VOL. 29 NO. 6

BULLETIN

OF THE

TORREY BOTANICAL CLUB

JUNE 1902

Chemical Studies of the Cocoanut with some Notes on the Changes during Germination *

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(WITH PLATE 19)

[From the Laboratory of Physiological Chemistry of Columbia University, and the New York Botanical Garden, New York.]

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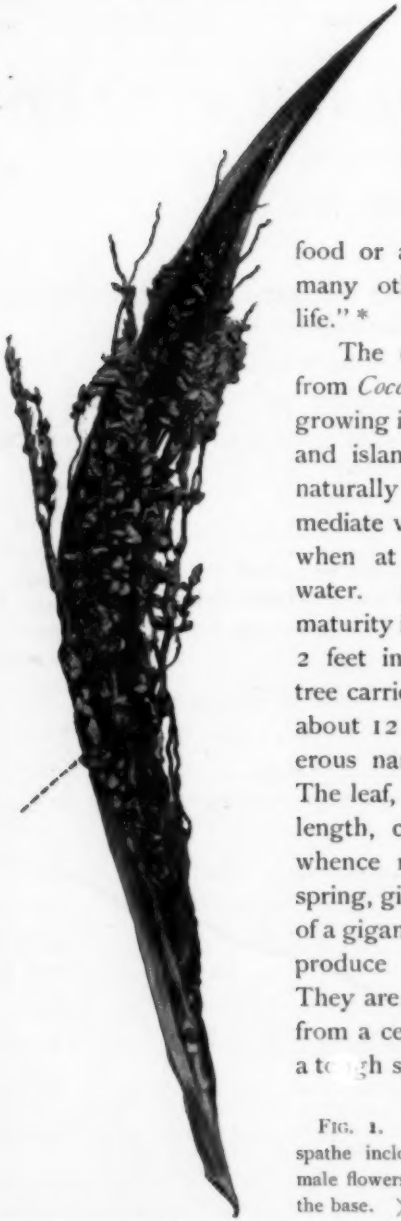
*Preliminary accounts of some of the results of this research were given in the Proceedings of the American Association for the Advancement of Science,— : 275. 1900, and in the Proceedings of the American Physiological Society. 1900: American Journal of Physiology, 5: 14. 1901.

The term "coco" appears to be derived from "coc" or "cocus," a local name for the "Indian nut," the fruit of *Cocos nucifera*, given to it on account of a fancied resemblance of the base of the endocarp, with its three circular impressions, to the face of a monkey when it utters a cry having a sound like the word. See *f. 1, pl. 19*. The term "cocoa" should be carefully distinguished from "cacao," the product of *Theobroma cacao*, from "coca" the derivative of *Erythroxylon coca*, from "coco," the coco-kola of commerce, and from "cocco" or "cocoa root" (*Colocasia esculenta*).

[Issued 20 June]

I. INTRODUCTION



"Of the whole class of seeds having the character of luxuries rather than of necessaries, the cocoanut is by far the most important to mankind, whether considered as a delicious and nutritious food or as supplying valuable oil and many other articles useful in social life." *

The common cocoanut is derived from *Cocos nucifera*, a species of palm growing in practically all tropical coasts and islands. The cocoa palm grows naturally on the seashore or in its immediate vicinity and does not bear well when at a great distance from salt water. (See analyses, p. 335.) At maturity it has a cylindrical stem about 2 feet in diameter. At its apex the tree carries a tuft of leaves, which are about 12 feet long. These have numerous narrow, rigid and long leaflets. The leaf, which may attain to 20 feet in length, consists of a strong mid-rib, whence numerous long acute leaflets spring, giving the whole the appearance of a gigantic feather. The flowers which produce the nut are yellowish-white. They are arranged in spikes, branching from a central axis, and inclosed with a tough spathe usually a meter or more

FIG. 1. Inflorescence of the cocoanut showing spathe inclosing the spikes, each with numerous male flowers above and a single female flower near the base. $\times \frac{1}{5}$. Winton.

* Smith: Food, 226. 1873.

in length. Their appearance and arrangement is shown in Fig. 1, on the opposite page. The tree grows to a height of about 60–100 feet and usually bears 80–100 nuts arranged on the tree in bunches of 10–20. It continues to bear during two generations of men.

The fruit is subtriangular-ovoid in form, about 12 inches long and 6 inches broad. It is composed of a thick, fibrous "husk" (exocarp) and thin, hard "shell" (endocarp), containing a white fleshy seed, the "meat" (endosperm), with a thin integument (testa). (See *Fig. 3*, p. 324.) The thick husk is remarkably adapted to the preservation of the seed, whilst the nut is tossed about by the waves until it reaches some shore, it may be, far distant from that on which it grew. While immature the nut is without the solid endosperm, but is filled with a milky fluid. As it ripens, however, the endosperm gradually develops and the milky juice diminishes in quantity. The temperature of this juice when fresh is always comparatively low. (See page 349 for further reference to the parts of the nut.)

FIG. 2. Half-grown cocoanut fruit with calyx, and axis from which the male flowers have fallen. × ½. Winton.

Figures 1, 2 and 3 are from cuts loaned to us by Dr. A. L. Winton, who used them lately in the account of his very valuable histological study of "The Anatomy of the Fruit of the *Cocos nucifera*."* We are greatly indebted to Dr. Winton for his kind assistance.

The cocoanut forms the chief food of the inhabitants of Ceylon, the South Sea Islands, the coast of Africa and other tropical coasts and islands.† The flesh is not only eaten as it comes from the tree, both ripe and unripe, but it is also prepared and served in various ways. In India the "copra" is much used as an ingredient of curries. It forms an accessory part of the diet, and is found

* Winton: American Journal of Science, IV. **12**: 265. 1901.

† The cocoanut is agreeable to the taste of various domestic and other animals, and is eagerly eaten by them. The cocoanut-crab (*Birgus latro*, suborder *Macrura*; anomalous form, approaching the *Brachyura* and closely related to the hermit crab) feeds almost entirely on the kernel of the cocoanut. Its powerful claws enable it to easily peel off the husk and open the hard shell.

in many of the confections, of civilized man all over the globe.*

Immoderate use of the fruit, which according to the people of the tropics is highly refrigerant, causes, it is said, rheumatic and other diseases.† The milk is considered an agreeable cooling beverage in the tropics. It has been known for some time that irritation of the mucous membrane of the bladder and urethra is caused by drinking too freely of the cocoanut milk.‡ It is strongly

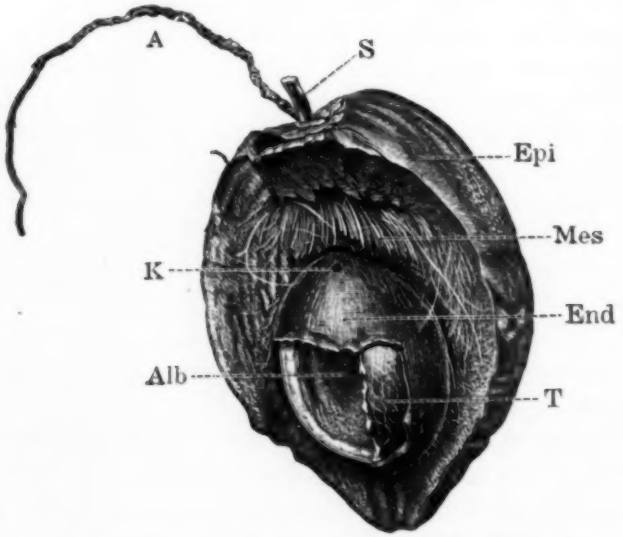


FIG. 3. Ripe cocoanut. *S*, lower part of axis forming the stem; *A*, upper end of axis with scars of male flowers; *Epi*, epicarp; *Mes*, mesocarp with fibers; *End*, endocarp or hard shell; *T*, portion of testa adhering to endosperm; *Alb*, endosperm surrounding cavity of the nut; *K*, germinating eye. × ½. Winton.

diuretic. Parisi has used the cocoanut therapeutically as an anthelmintic with uniformly satisfactory results.§ He states that the meat of the nut is a powerful *taenicide*, the milk sharing the prop-

* In the Annals of the New York Academy of Science, 13: 490, 1900–1901, the following may be found: "Dr. Gies in answer to a question stated that the food content of the cocoanut is small." This answer is quoted incorrectly. The question referred to the *nitrogenous* food content. It was stated on that occasion that the "content of *proteid* food-stuff is small." See page 340.

† Pavy: A Treatise on Food and Dietetics physiologically and therapeutically considered, 488. 1878.

‡ Curtis: Annals of the New York Academy of Sciences, 13: 490. 1900–1901.

§ See Liebreich: Encyklopaedie der Therapie, 1: 744. 1896.

erty.* The cocoanut has been used as a vermifuge in India for probably forty generations by the beef eaters of that country and is there well known as a means of expelling the flat worm.† The small, green and immature nut is grated fine for medicinal use, and when mixed with the oil of the ripe nut becomes a healing ointment.

The fibrous husk (coir) is widely used for the construction of ropes, brushes, bags, matting, etc. The compact fleshy edible portion (copra), closely lining the hard shell and which is entirely fluid or gelatinous when young, contains a large proportion of fat, which is extracted and used for various commercial purposes, such as the manufacture of fine soaps and candles and frequently as a substitute for butter. Cocoanut oil and resin melted together yield a substance capable of being used with success in filling up the seams of boats and ships, and in tropical countries for covering the corks of bottles as a protection against the depredations of the white ant. A quart of the oil may be obtained from six to ten nuts. The hard shell is easily polished and lends itself to the formation of various utensils and ornaments. It also has a high fuel value.

Although considerable is known of the constituents of the cocoanut, of its nutritive value and commercial uses, little has been done to ascertain the nature of the changes which the nut undergoes during germination. At the suggestion of Dr. MacDougal we have undertaken such a study, more especially from the chemical standpoint, and although our work in this particular connection has not been quite as fruitful as we had hoped it might be, our results are not without some interest.

II. Chemical Composition of the ungerminated Cocoanut

Before beginning our work on the germinating seed we felt it desirable to make ourselves thoroughly familiar with the chemical qualities of the ungerminated nut. This seemed all the more desirable because of the incomplete as well as the disconnected chemical data thus far recorded in this connection. This purpose was accomplished in a large number of analyses of numerous

* United States Dispensatory, 1619. 1899.

† American Journal of the Medical Sciences, **67**: 281. 1889.

samples. We record the more important of these results, with comparative data from the work of others, on the following pages.

Most of the nuts subjected to the analyses referred to farther on were furnished to us for this work by Hon. Wm. Fawcett and the United Fruit Co., who sent them in their husks from Jamaica. They were ripe, fresh and of about the average size. A few determinations were made with material from nuts bought in the markets in this city—source unknown, though doubtless of West Indian origin. These were of ordinary size, appeared to be ripe and fresh, and gave essentially the same analytic results as those obtained directly from Jamaica.*

We wish at the outset of this paper to thank Dr. MacDougal not only for the supply of material with which he favored us, but also for the suggestions which led us to undertake this work and for the kind encouragement he has given us from the beginning.

PROPORTIONS OF MILK, ENDOSPERM AND SHELL IN THE HUSKED NUT.—The weights and proportions of the main parts of the nut without its husk were carefully ascertained in special observations, as well as incidentally in other experiments.† The milk was removed as indicated on page 328. The empty nut was quickly broken with a hammer, the endosperm and germ, with the thin seed coat, carefully and promptly removed with a knife, and the fresh moist parts weighed at once. The results given on the opposite page were obtained in this connection.‡

The only results recorded on these gross relationships that we have been able to find were those obtained in a single experiment by v. Ollech, and those by Bachofeu.§ The parts of a single cocoanut, except the milk, were dried in the air by v. Ollech.‖

* A few showed signs of deterioration, such as "popping" on opening, free acid in the milk, etc. These were, of course, discarded.

† The weight of the fibrous husk varies considerably, as the amount of moisture increases by absorption or decreases by evaporation. The weights of the other parts are ordinarily not subject to such fluctuations.

‡ The weights of the germ and the thin seed coat enveloping the endosperm were included with the latter.

§ See also Berzelius: Lehrbuch der Chemie. Translated by Wöhler, 7: 533. 1838.

‖ v. Ollech: Quoted by König, Die menschlichen Nahrungs- und Genussmittel, etc., 2: 495. 1893.

FRESHLY IMPORTED NUTS (FROM JAMAICA).

Number.	Weights in Grams.				Percentage of total Weight of husked Nut.			Milk.	
	Fruit without Husk.	Shell.	Endosperm with Germ and Integument.	Milk.	Shell.	Endosperm with Germ and Integument.	Milk.	Vol. c.c.	Specific Gravity.
1	845	255	437	153	30.2	51.7	18.1	150	1018
2	771	198	379	194	25.7	49.2	25.1	190	1017
3	658	168	371	119	25.5	56.4	18.1	117	1020
4	718	199	351	168	27.7	48.9	23.4	164	1019
5	597	152	327	118	25.5	54.8	19.7	113	1022
6	463	127	251	85	27.4	54.2	18 4	83	1019
7	622	195	334	93	31.3	53.7	15.0	90	1023
8	563	144	329	90	25.6	58.4	16.0	87	1027
9	633	166	374	93	26.2	59.1	14.7	90	1027
10	530	156	282	92	29.4	53.2	17.4	90	1021
11	637	150	363	124	23.5	57.0	19.5	121	1024
12	497	144	267	86	29.0	53.7	17.3	85	1014
13	538	162	283	93	30.1	52.6	17.3	90	1021
14	413	123	256	34	29.8	62.0	8.2	33	1030
15	511	158	309	44	30.9	60.5	8.6	43	1037
16	578	190	320	68	32.8	55.4	11.8	67	1016
17	568	142	350	76	25.0	61.6	13.4	74	1026
18	495	140	293	62	28.3	59.2	12.5	60	1024
19	813	221	392	200	27.2	48.2	24.6	194	1021
20	758	208	393	157	27.4	51.9	20.7	150	1022
21	584	148	339	97	25 4	58.0	16 6	94	1028
Aver.	609	169	333	107	27.8	55.2	17.0	104	1023

NUTS FROM THE MARKET (NEW YORK CITY).

1	1070	250	558	262	23.4	52.2	24.4	254	1018
2	1009	251	506	252	24.9	50.1	25.0	246	1015
3	728	202	417	109	27.7	57.3	15.0	106	1027
4	800	226	450	124	28.2	56.3	15.5	120	1026
5	688	191	385	112	27.8	56.0	16.2	110	1015
6	565	131	316	118	23.2	56.0	20.8	116	1017
7	639	210	382	47	32.9	59.8	7.3	46	1024
8	638	210	311	117	32.9	48.8	18.3	115	1017
9	480	125	304	51	26.0	63.3	10.7	48	1034
10	561	158	307	96	28.2	54.7	17.1	92	1024
11	733	204	414	115	27.8	56.5	15.7	110	1024
12	762	176	380	206	23.1	49.9	27.0	202	1020
Aver.	722	194	394	134	27.1	55.1	17.8	130	1021

They represented the following proportions of the total weight, which was 1,133 grams:

Fibrous Husk.	Shell.	Endosperm with Germ.*	Milk.
30.45 per cent.	19.59 per cent.	37.78 per cent.	12.18 per cent.

Of the total weight of the husked nut, which, by calculation, must

* Including, doubtless, the seed coat as well.

have been 788 grams, the percentages of the parts were (calculated by us):

Shell.	Endosperm with Germ.	Milk.
28.17 per cent.	54.32 per cent.	17.51 per cent.

These results, it will be observed, harmonize closely with the averages of our own determinations.

The data obtained by Bachofeu in this connection will be found in the table on page 335.*

COMPOSITION OF THE MILK.—The milk was poured from the nut through an opening made in the "eye" of the fertile carpel (see page 350) with a cork-borer. Extraneous matter could easily be kept out of the milk by this procedure and, besides, the fluid could be obtained when desired in a perfectly fresh, unevaporated condition.

The milk was found to be faintly turbid and opalescent in each case, and always contained a few oil globules and occasionally crystalline matter. It was acid in reaction to litmus although, as shown by lacmoid, no free acid was present in the normal fluid. The reaction is due to acid phosphate. Both alkali and earthy phosphate are present. The latter can be precipitated, in part at least, on boiling. An abundant precipitate of phosphate is obtained when the milk is made alkaline. The average specific gravity, determined with the aid of a hydrometer, was, as already noted on page 327, 1,023 and 1,021. The average specific gravity of the mixed milk of 15 nuts not included in the table on that page was 1,023. Of eight additional nuts not referred to there, and examined at another time, the figures for the mixed milk were 1,022.

The milk reduces Fehling's and Nylander's solutions and it ferments. It contains some monosaccharide which, from the characters of the phenylosazone derivatives, appears to consist of either dextrose or galactose, probably of both. Disaccharide in the form of cane-sugar is also present in good quantity, as might be inferred from the sweet taste of the milk.

* Results having some relation to these are given by Atwater: Report of the Storrs (Conn.) Agricultural Experiment Station, 123. 1899. Hammerbacher (Landwirtschaftlichen Versuchs-Stationen, etc., 18: 472. 1875) found that the endosperm of two nuts weighed 835.8 grams; the milk, 303.95 grams. See also, pages 331 and 356.

On standing the milk turns sour, becomes thicker, and has much the odor and physical appearance of soured cow's milk. The milk ferments readily. As it does so the acidity increases with a production of acid from the sugar. Alcohols are also produced in the process. The distillate from the fermented milk has an agreeable taste and an alcoholic odor.*

Chlorides are prominent with phosphates among the inorganic substances of the milk. It contains only a very small quantity of proteid, coagulating above 80° C., and also traces of a proteose-like body. Very faint biuret and xanthoproteic reactions were obtainable with the fresh fluid. A snow-white precipitate consisting in part of earthy phosphate is obtained on warming the milk on the water-bath at 70° C. The filtrate from this product when boiled yields a delicate turbidity of coagulated proteid which becomes flocculent on addition of a slight excess of acetic acid. The filtrate from this coagulum gives only a very faint biuret reaction. Cocoanut milk is said to contain malate of lime.†

GENERAL COMPOSITION OF THE MILK

No.	Milk Used.		Percentage of Fresh Milk.				Percentage of Solids.	
	Specific Gravity.	Grams.	Water.	Solid Matter.			Organic Matter.	Inorganic Matter.
				Total.	Organic.	Inorganic.		
1–*a*	1019	28.815	95.52	4.48	3.98	0.50	88.84	11.16
b		27.280	95.43	4.57	4.05	0.52	88.60	11.40
2–*a*	1020	25.403	95.28	4.72	4.27	0.45	90.58	9.42
b		27.837	95.44	4.56	4.14	0.42	90.70	9.30
3–*a*	1022	30.382	94.73	5.27	4.78	0.49	90.57	9.43
b		28.528	94.62	5.38	4.90	0.48	91.02	8.98
4–*a*	1016	25.958	95.73	4.27	3.88	0.39	90.81	9.19
b		25.823	95.65	4.35	3.96	0.39	90.92	9.08
c		26.298	95.68	4.32	3.91	0.41	90.57	9.43
5–*a*	1021	29.416	95.11	4.89	4.47	0.42	91.38	8.62
b		29.467	95.23	4.77	4.36	0.41	91.39	8.61
c		24.667	95.24	4.76	4.35	0.41	91.31	8.69
6–*a*	1024	23.119	95.44	4.56	3.82	0.74	83.68	16.32
b		23.886	95.33	4.67	3.92	0.75	84.04	15.96
7–*a*	1028	22 540	94.80	5 20	4.18	1.02	80.38	19.62
b		26.690	94.94	5.06	——	——	——	——
8–*a*	1027	28.722	95.02	4.98	4.21	0.77	84.45	15.55
b		28.409	94.97	5.03	4.26	0.77	84.69	15.31
Aver.	1022	26.847	95.23	4.77	4.21	0.56	88.47	11.53

* Cocoa beer, containing 3.4 per cent. "Extractive," has been made by Calmette: Chemisches Centralblatt, 2: 394. 1894.

† Harley and Harley: Proceedings of the Royal Society of London, 43: 464. 1887–88.

On evaporation to a small volume on a water-bath the fresh milk becomes darker in color, takes on an odor characteristic of sugar syrups and looks not unlike molasses. Cane-sugar crystallizes from it in abundance on cooling.

The analytic data given on page 329 were obtained in our study of the general composition of the perfectly fresh milk of the Jamaican nuts.*

Percentage results in this connection had been obtained previously as follows:

Water.	Solids.	Organic Matter.	Inorganic Matter.	Nitrogenous Substance.	Fat.	Nitrogen-free Extractives	Carbohydrates.
91.50†	8.50	7.31	1.19	0.46	0.07	6.78	—
91.37‡	8.63	7.50	1.13	0.38	0.11	—	7.01§

These results were obtained with milk from nuts grown in the eastern hemisphere. The milk from the Jamaican nuts appears, as we have seen, to contain less solid matter, both organic and inorganic. This difference is emphasized by Hammerbacher's¶ observations on the specific gravity of cocoa-milk. He describes the milk as a colorless, slightly opalescent fluid with a specific gravity at 20° C. of 1044.** The milk from two nuts weighed 303.95 grams. From the nitrogen-free extractive substance in 77.8 grams of milk contained in a third nut, 0.8504 gram of dextrose was obtained. When milk was warmed with dilute sulphuric acid an odor of volatile fatty acid became perceptible. A crystalline barium salt was prepared from the distillate of the acidified milk which was found to consist of barium propionate.

The milk contains a small amount of diastatic ferment and also oxidase.†† We were unable to detect any other enzymes.

The following results were obtained by van Slyke‡‡ in his comparative studies of the milk of six *unripe* nuts and of one ripe one:

* The methods of analysis used for this and similar purposes, throughout our work, were those commonly employed in the laboratory. See Vandegrift and Gies: American Journal of Physiology, 5: 287. 1901.

† Hammerbacher: Landwirtschaftlichen Versuchs-Stationen, etc., 18: 472. 1875.

‡ König: Menschlichen Nahrungs- und Genussmittel, etc., 2: 308. 1893. See also Bizio: Pharmaceutisches Centralblatt, 756. 1833.

§ Including 4.42 per cent of cane-sugar. See page 328.

¶ Hammerbacher, *loc. cit.*

** See our large number of determinations of specific gravity on page 327. Also references on pages 328 and 329.

†† Hunger: Journal of the Society of Chemical Industry, 20: 1030. 1901.

‡‡ Van Slyke: Chemisches Centralblatt, 1: 595. 1891. Compare with results on page 329.

Constituents.	Milk of unripe Nuts.							Milk of ripe Nut.
	1	2	3	4	5	6	Average 1–6.	
Weight in grams. . .	230.5	378.6	347.0	383.7	350.0	330.0	336.6	109.6
Specific gravity . . .	1,024.6	1,023.0	1,022.3	1,023.0	1,022.1	1,021.5	1,022.8	1,044.0
Water (per cent.)	94.37	94.48	94.59	94.89	95.27	96.43	95.01	91.23
Total solid matter (%)	5.63	5.52	5.41	5.11	4.73	3.57	4.99	8.77
Inorganic substance.	0.575	0.635	0.675	0.611	0.658	0.602	0.626	1.06
Glucose	4.58	3.83	3.45	4.06	4.36	3.56	3.97	Trace.
Cane-sugar. . .	Trace	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	4.42
"Albuminoid" . .	0.120	0.126	0.114	0.205	0.140	0 095	0.133	0.291
Fat . .	0.084	0.100	0.138	0 131	0.145	0.120	0.120	0.145

The chief chemical differences induced by growth, as indicated by the above results, are an increase in the proportion of solid matter, including ash, fat and nitrogenous substance. Glucose almost entirely disappears from the milk of the ripe nut, cane-sugar replacing it—a fact evidencing synthetic production of disaccharide from monosaccharide.

Hammerbacher, believing that the endosperm develops directly from the milk, determined the quantitative relationships of the saline matters contained in each part from the same nut. He gives the following as his percentage results:

	Ash of the Milk.	Ash of the Endosperm.*
Potassium,	55.200	43 882
Sodium,	0.728	8.392
Calcium,	3.679	4 628
Magnesium,	6.606	9.438
Chlorine,	10.373	13.419
Phosphoric acid,	20.510	16.992
Sulphuric acid,	5.235	5.091
Silicic acid,	——	0.500
	102.331	102.342
Minus oxygen for chlorine,	2.338	3.024
	99.993	99.318

The above results indicate a particular increase of the content of sodium chloride in the ash of the developing endosperm and a corresponding decrease of potassium phosphate. See pages 322 and 335. The amount of silicic acid in the endosperm is also noteworthy. See page 335.

ENDOSPERM. *General Composition.*—The pure white kernel

* Compare with results of Bachofeu's analysis, given on page 335. Our own results were the same as these qualitatively. See also Schaedler Technologie der Fette und Oele des Pflanzen- und Thierreichs, 840, 1892, who found 3.60 per cent. of iron in the ash of the endosperm in addition to the above constituents.

or "meat" of the nut is fibrous in structure, closely lines the shell, is from 1 to 2 cm. thick, and contains a very large proportion of fat. It is the part used most frequently for dietetic purposes. It possesses a characteristic and pleasant odor and is very agreeable to the taste. The endosperm cells do not contain starch granules, but fat needles and proteid lumps are present in them. The proteid particles are partly crystalline.*

After the kernel has been finely divided in a meat chopper, the resultant hash may be subjected to increasing pressure, when an

GENERAL COMPOSITION OF THE ENDOSPERM

No	Endosperm used.	Percentage of fresh Endosperm.				Percentage of Solids.	
	Grams.	Water.	Solid Matter.			Organic Matter.	Inorganic Matter.
			Total.	Organic.	Inorganic.		
1–*a*	8.467	47.70	52.30	51.19	1.11	97.88	2.12
b	9.728	42.10	57.90	56.79	1.11	98.09	1.91
c	10.900	46.60	53.40	52.34	1.06	98.01	1.99
2–*a*	11.885	48.31	51.69	50.65	1.04	98.01	1.99
b	12.151	48.90	51.10	50.01	1.09	97.87	2.13
c	11.707	52.29	47.71	46.61	1.10	97.69	2.31
3–*a*	8.762	43.90	56.10	55.20	0.90	98.39	1.61
b	8.185	47.73	52.27	51.20	1.07	97.95	2.05
c	8.923	46.31	53.69	52.71	0.98	98.18	1.82
4–*a*	11.511	47.89	52.11	51.05	1.06	97.97	2.03
b	9.501	46.90	53.10	52.05	1.05	98.02	1.98
c	9.244	47.50	52.50	51.43	1.07	97.96	2.04
5–*a*	8.942	42.80	57.20	56.17	1.03	98.21	1.79
b	9.312	43.79	56.21	55.21	1.00	98.23	1.77
6–*a*	10.214	50.30	49.70	48.68	1.02	97.95	2.05
b	10 624	48.70	51.30	50.28	1.02	98.02	1.98
7–*a*	10.746	42.21	57.79	56.83	0.96	98.34	1.66
b	10.142	39.60	60.40	59.46	0.94	98.45	1.55
Aver.	10.052	46.31	53.69	52.66	1.03	98.07	1.93

oily juice is obtained from it. The filtrate from this turbid mixture has a higher specific gravity than the milk of the nut, is acid in reaction, reduces Fehling's solution, contains a dextrin-like body and the milk salts, gives the proteid color reactions, yields coagulable proteid, and on dilution with water becomes turbid from precipitated globulin.

The data given above were obtained for general composition of the endosperm immediately after the nuts were opened.†

* See pages 342 and 352.

† The methods were the same as those employed with the milk. The thin seed-coat was trimmed off and the pieces of kernel cut into small, thin pieces with a knife. The material was taken from all parts of the nut.

Comparison of the averages given on the opposite page may be made with the following previously recorded results for the fresh endosperm from nuts of eastern origin: *

Fresh Endosperm				Dry Endosperm	
Water.	Total Solids.	Organic Matter.	Inorganic Matter.	Organic Matter.	Inorganic Matter.
46.64	53.36	52.39	0.97	98.20	1.80

The agreement is seen to be very close.

By reason of the dietetic and commercial values of the various constituents of the endosperm of the cocoa fruit, numerous products of the kernel have been made and analyzed. The air-dried endosperm, or so-called "copra," is shipped in large quantities from the tropics. Cocoa-oil is obtained from the copra by various methods in countries distant from the tropics, the solid residues remaining after extraction serving various purposes. This residue makes up the so-called "cocoa-cake" obtained in the process of expressing the oil at various degrees of temperature. It is also ground into "cocoa-meal." In both forms, the residual substance

Products Analyzed.	Water.	Total Solids.	Organic Matter.				Inorganic Matter.
			Nitrogenous Substance.	Fat.	N-free Extractive.	Crude Fiber.	
Air-dried endosperm or copra.†	5.81	94.19	8.88	67.00	12.44	4.06	1.81
Endosperm, perfectly dried.‡	——	100.00	10.29	67.35	15.11	5.42	1.83
Endosperm, free from fat and water.‡	——	100.00	31.49	——	46.25	16.69	5.57
"Cocoa-cake." §	10.30	89.70	19.70	11.00	38.70	14.40	5.90
"Cocoa-meal." ‖	11.12	88.88	17.94	10.88	35.34	17.40	7.32
"Cocoa-meal," after extraction of oil. ¶	4.55	95.45	23.20	1.85	64.45		5 95

* Hammerbacher: Landwirtschaftlichen Versuchs-Stationen, etc., **18**: 472. 1875. See also Bizio: Pharmaceutisches Centralblatt, 757. 1833.

† König: Menschlichen Nahrungs- und Genussmittel, etc., **2**: 652. 1893. Also p. 308.

‡ Hammerbacher: Landwirtschaftlichen Versuchs-Stationen, etc., **18**: 472. 1875.

§ Dietrich und König: Zusammensetzung und Verdaulichkeit der Futtermittel, **2**: 1031. 1891.

‖ Dietrich und König: *ibid.*, **1**: 725.

¶ Schaedler: Technologie der Fette und Oele des Pflanzen- und Thierreichs, 624. 1892. (*a*) For references to digestibility and nutritive value of cocoa-cake see results of experiments on pigs and sheep given by Dietrich and König, **2**: 1031, 1036, 1040, 1123. (*b*) Compare above results with the table for general composition on the opposite page.

is used as food for cattle and as a fertilizer, having special value in both these connections.* It is sometimes also used illicitly as a food adulterant.

The analytic percentage results on page 333 have been reported by various agricultural chemists for such products from nuts grown in the eastern hemisphere.

The following summary of facts connected particularly with food value was given several years ago by Woods and Merrill: †

	Refuse.	Water.	Proteid.	Fat.	Total carbohydrates.	Ash.	Fuel value per pound; calories.
Edible portion,	——	14.1	5.7	50.6	27.9	1.7	2,986
As purchased,	48.8	7.2	2.9	25.9	14.3	.9	1,529
Without milk, as purchased,	37.3	8.9	3.6	31.7	17.5	1.0	1,872
Cocoanut milk, as purchased,	——	92.7	.4	1.5	4.6	.8	97
Shredded cocoanut,	——	4.3	6.5	63.7	24.1	1.4	
Shredded cocoanut,	——	2.8	6.0	51.0	39.0	1.2	
Edible portion,	——	5.8	8.9	67.0	16.5	1.8	
Cocoanut milk,	——	91.5	.5	.1	6.8	1.2	

Through the kindness of Dr. MacDougal we have been able to examine an account of "The cocoanut and plant vitality" in the Bulletin of the Botanical Department of Trinidad (July, 1900, p. 249). Reference is therein made to the report of Bachofeu in the Queensland Agricultural Journal for April, 1900. Bachofeu says: "Though there exist several analyses of parts of the cocoanut, no one seems to have undertaken the task of getting a complete analysis made with the view of ascertaining the actual demand made by the cocoanut upon the mineral constituents of the soil."

The results obtained by Bachofeu for a single nut are so complete, and so general in their interest and application that we quote, on page 335, his general summary in its entirety. ‡

Bachofeu's results indicate that sodium chloride and potassium phosphate are the chief inorganic matters drawn upon in the development of the cocoanut—chemical data in harmony with the fact

* v. Knieriem: Chemisches Centralblatt, 2: 672. 1898.

† Woods and Merrill: Bulletin, Maine Agricultural Experiment Station, No. 54; 81. 1899.

‡ The analyses were made in Ceylon. Native nuts were used.

that the cocoa palm does not thrive away from the coast or where salt is lacking in the soil. See second table, page 331.

BACHOFEU'S ANALYSIS OF THE COCOANUT

	Husk.	Shell.	Kernel.	Milk.
Total weight in lbs.	2.702	0.546	0.875	0.503
" " in per cent.	57.28	11.59	18.54	12.58
* { Moisture in per cent.	65.56	15.20	52.80	——
* { Dry matter in per cent.	34.44	84.80	47.20	——
Pure ash in per cent., containing viz:	1.63	0.29	0.79	0.38
Silica, SiO_2.	8.22	4.64	1.31	2.95
Oxide of iron and alumina, $Fe_2O_3Al_2O_3$.	0.54	1.39	0.59	Trace.
Lime, CaO.	4.14	6 26	3.10	7.43
Magnesia, MgO.	2.19	1.32	1 98	3.97
† Potash, K_2O.	30.71	45.01	45.84	8.62
Soda, Na_2O.	3.19	15.42	——	——
† Potassium chloride, KCl.	——	——	13.04	41.09
Sodium chloride, NaCl.	45.95	15.56	5.01	26 32
Phosphoric acid, P_2O_5.	1.92	4.64	20.33	5.68
Sulphuric acid, SO_3.	3.13	5.75	8.79	3.94
	100.00	99.99	99.99	100.00
† Containing total potash, K_2O.	30.71	45.01	54.05	34.54
* Containing nitrogen, N.	0.137	0.100	0.504	——

Thus of the more important ingredients of the soil 1,000 nuts remove the following:

In Lbs.	Husk.	Shell.	Kernel.	Milk.	Total Lbs.
Nitrogen, N.	3.7017	0.5460	4.4100	——	8.6577
Phosphoric acid, P_2O_5.	0.8456	0.0735	1.4053	0.1279	2.4523
Potash, K_2O.	13.5255	0.7127	3.7362	0.7783	18.7527
Lime, CaO.	1.8234	0.0991	0.2143	0.1674	2.3042
Sodium chloride, NaCl.	20.2375	0.2464	0.3563	0.5431	21.4233

Fat.—The striking chemical characteristic of the endosperm is its large content of oil. This may readily be extracted with fluids like ether. It can also be obtained in large proportion by pressure, particularly at the tropical temperatures. The fat has the consistence of butter in northern countries and possesses, when fresh, a fragrant and characteristic odor and an agreeable taste. It is snow white, sometimes cream-colored and readily crystallizes in large rosettes from the molten condition or from its alcohol or ethereal solutions. These crystals closely resemble those of palmitic acid. They melt at about 20–23° C., and congeal again several degrees below the melting point. They are fairly soluble in cold alcohol. Although cocoa-fat differs somewhat in composition in different countries, it has been found that the variations are comparatively slight. The temperature at which the oil is expressed influences

these variations by increasing or decreasing the proportion of fats melting only at higher temperatures. These facts account for the variations in the figures given for melting point. Its specific gravity is 0.9+.

On heating to about 170° C., the oil gives off the odor of lactic acid; at a temperature of 300° C. acrolein may be detected. On long-continued heating with nitric acid the following dibasic acids are formed: succinic, adipic, pimelic, suberic and azelaic. Nitrocaproic acid is also formed.* The oil is very soluble in all of the well-known fat solvents. It contains some free fatty acid, but consists chiefly of glycerides of caprylic, lauric, myristic and palmitic acids.† Glycerides of caproic and capric acids are present in appreciable quantity; also a trace of stearin and some olein.‡ The fat dissolves readily at a comparatively low temperature in an equal quantity of glacial acetic acid. Such a solution becomes turbid at 40° C.§ By reason of its content of lower fatty acid radicles cocoa-oil has a high saponification value. Cocoa-oil is particularly resistent to the hydrating effect of superheated steam.‖

The following data were obtained for the percentage fat-content in the fresh endosperm. The method of determination used was Dormeyer's:¶

	1	2	3	4	5	6	7	Gen'l Average.
Fresh endosperm, *a*.	38.27	40.01	36.71	35.10	34.60	38.90	38.60	
b.	36.14	40.54	35.02	34.90	34.10	40.70	38.40	
Average,	37.20	40.28	35.87	35.00	34.35	39.80	38.50	37.29

The ether extracts containing the oil were free from lecithin

* Schaedler: Technologie der Fette und Oele des Pflanzen- und Thierrichs, 843. 1892.

† The presence of palmitin (tri) is doubted by Ulzer: Chemisches Centralblatt, II: 1143. 1899.

‡ The so-called "cocinic acid" or "cocostearic acid" derivable from "cocin" or "cocinin" is, like the latter, a mixture. The former is a mixture of some of the above fatty acids; the latter of their glycerides. See Oudemans: Chemisches Centralblatt, 192. 1861.

§ Valenta. Quoted by Vaubel: Physikalischen und chemischen Methoden quantitativen Bestimmung organischer Verbindungen, 1: 162. 1902.

‖ Klimont: Journal of the Society of Chemical Industry, 21: 126. 1902.

¶ Dormeyer: Jahresbericht über die Fortschritte der Thier-Chemie, 26: 42. 1896. The fresh tissue was finely divided and weighed, then dried to constant weight at 100–105° C., and all of it extracted with anhydrous sulphuric ether. The usual amounts of tissue were used.

and could be almost entirely saponified. Hammerbacher * in the saponification of 25 grams of the pure oil obtained the following results:

	Grams.	Per Cent.
Fatty acids convertible into *insoluble* lead salts,	15.1488	60.595
Fatty acids convertible into *soluble* lead salts,	9.5282	38.113
Glycerin,	0.5596	2.238
Total,	25.2366	100.946

The excess in weight of products is explained by the addition of hydroxyl groups in the cleavage of the triglycerides. König had previously found the glycerin content of cocoa-fat to be 2.08 per cent. Hammerbacher therefore concludes: "It follows from these results that this vegetable fat consists in greatest part of *free* fatty acid."

That there is some error in this conclusion, however, is evident from the results of later work. Benedikt † reports the glycerin content of cocoa-oil to be 13.3–14.5 per cent. Crossley and Le Suer found that the content of *free* fatty acid in terms of oleic acid varied between 2.50 and 8.86 per cent.‡

Stellwaag ‖ studied the fat extracted from cocoa cakes. This oil was rancid, of course. He found the quantity of *free* fatty acid to be only 9.84 per cent. The fat from the ether extract melted at 23° C. The saponification figure was 244.4. The extract contained 81.14 per cent. of neutral fat. The amount of unsaponifiable matter was 0.51 per cent. The molecular weight of the fatty acids was given as 207.¶

Studied through the oleo refractometer of Amagat and Jean, cocoa-oil is found to rotate to the left like an animal fat.**

The composition of cocoa-oil as determined by König †† is:

C.	H.	O.
74.15 per cent.	11.73 per cent.	14.12 per cent.

* Hammerbacher: Landwirtschaftlichen Versuchs-Stationen, etc., **18**: 472. 1875.

† Benedikt und Zsigmondy: Chemiker Zeitung, **9**: 975. 1885.

‡ Crossley and Le Suer. Quoted by Hopkins: Oil-Chemists' Handbook, 38, table iv. 1900.

‖ Stellwaag: Landwirtschaftlichen Versuchs-Stationen, etc., **37**: 135. 1890.

¶ See also König, Menschlichen Nahrungs- und Genussmittel, etc., **2**: 389. 1893.

** Blyth: Foods, Their Composition and Analysis, 359. 1896.

†† König: *loc. cit.*, **2**: 385. See also, Brandes, Pharmaceutisches Centralblatt, 751. 1838.

The following facts regarding cocoa-oil have been compiled from various sources. They may be compared with similar data for other fats and oils given in the standard works of König, Staedeler, Lewkowitsch and others:

A. The heat of combustion of cocoa-oil is 9,066 small calories per gram.* It is as low as that of any other fat; slightly lower than butter. This is due to the fact that it contains a large proportion of fatty acids of low molecular weight.

B. Melting point is at 24° C. Congealing temperature is 22–23° C. Fatty acids from it melt at 24.6° C. They congeal at 19° C.†

C. Saponification value = 257.3–268.4‡

D. Iodine number = 9.0–9.5; same for its fatty acids = 8.5–9.0.§

E. Specific gravity = 0.9115 at 40° C.‖

F. Acid value = 9.95–35.21.

G. Reichert-Meissl figure = 7.4; Hehner = 88.6–90.5.

H. Barium figure (König-Hart) = 117–120.

I. Molecular weight of the mixed fatty acids = 196–211.

The use of cocoa-fat and other cheap vegetable oils as a substitute for butter among the poorer classes has been increasing. Cocoa-fat is better adapted for cooking than for table use. It is frequently employed as an adulterant of ordinary butter. Prepared cocoa-fat makes a fairly good substitute for common butter. The fresh material becomes rancid after a time, because of its accumulating content of free fatty acid resulting from bacterial agency. Volatile acids are formed. Its tendency to rancidity is not as great, however, as that of animal fats. The fatty acid present in the fat to begin with can easily be removed with insoluble basic compounds, such as magnesia. By this means

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* Merrill. Quoted by Sherman and Snell: Journal of the American Chemical Society, **23**: 166. 1901.

† König: Menschlichen Nahrungs- und Genussmittel, etc., **2**: 322. 1893.

‡ König: *Ibid.*

§ Benedikt. Quoted by Vaubel: Physikalischen und chemischen Methoden quantitativen Bestimmung organischer Verbindungen, **2**: 235. 1902.

‖ Values given after E–I inclusive are quoted by Hopkins: Oil-Chemists' Handbook, 38, table iv. 1900. See also Lane: Journal of the Society of Chemical Industry, **20**: 1083. 1901.

a "butter" is made from this oil which has the merit of enduring hot climates without becoming rancid. This product has been recommended for military and naval uses.*

Among the prominent commercial products is the cocoa-butter made in Mannheim, Germany.† König‡ found this product to have the following percentage composition:

Water.	Solids.	Organic Matter.	Inorganic Matter.	Fat.	Fatty Acid.	Nitrogenous Substance.
0.15	99.85	99.848	0.002	99.848	trace.	trace.

It has been stated that cocoa-butter is not very easily digested and that it does not agree with sick people.§ The recent researches of Bourot and Jean,‖ however, show that a specially prepared cocoa-butter melting at 31° C. and containing only a trace of free fatty acid, is quite as easily and completely digested as ordinary butter.¶

We have already alluded to some of the commercial uses to which cocoa-fat is put. Soaps made from it combine with or hold an unusual amount of water while still retaining special hardness, one pound of the oil yielding three pounds of soap.** It is thus well adapted for the preparation of toilet soaps. The soaps made from cocoa-oil are characterized by great solubility in salt solution and can be precipitated from such fluid only by the addition of a very large excess of salt. The so-called "marine" or "salt water soap" has the property of dissolving as well in salt water as in fresh water and is made of cocoa-oil and soda.††

* Rusby: Reference Handbook of the Medical Sciences, 3: 164. 1901.

† See Leffman and Beam: Select Methods in Food Analysis, 182. 1901.

‡ König: Menschlichen Nahrungs- und Genussmittel, etc., 2: 309. 1893. See also Schaedler, Technologie der Fette und Oele des Pflanzen- und Thierreichs, 1340. 1892.

§ Liebreich: Encyklopaedie der Therapie, 1: 744. 1896.

‖ Bourot und Jean: Jahresbericht uber die Fortschritte der Their-Chemie, 26: 58. 1896. See also v. Knieriem, Chemisches Centralblatt, 2: 672. 1898.

¶ "Cocoanut cream," a dietary product much used in the tropics, is made by grating the endosperm and squeezing through cloth the fluid from the finely divided material. In a warm climate the resultant mixture contains much oil and is a very delicious accessory food. Besides the oil, the "cream" contains chiefly carbohydrate and proteid. See page 332 for references to similar fluid obtained from the endosperm by pressure in our own experiments.

** Ebermayer: Physiologische Chemie der Pflanzen, 344. 1882. See also Joss, Pharmaceutisches Centralblatt, 449. 1834.

†† See Schaedler, Technologie der Fette und Oele des Pflanzen- und Thiereichs, 1178–1188, 1892, where may be found the results for percentage composition of the sodium soap, given at the bottom of the next page:

The harder fats of the oil make excellent candles. They are used also as constituents for suppositories and related therapeutic products. Medicinally the oil is employed repeatedly as a substitute for lard, olive oil and cod-liver oil. It is also made the chief substance by bulk in various salves and in cold cream, pomade and similar cosmetic preparations. In ointments and cerates it is especially valuable because of its ready absorption when rubbed on the surface of the body; further, it takes up an unusual amount of water—a useful quality when it is desired to apply saline solutions externally. It shows little tendency to produce chemical changes in substances with which it may be associated.

Crude Fiber and Carbohydrates.—Cellulose is a prominent constituent of the endosperm. Associated with the fibrous elements is a polysaccharide, present in comparatively large quantity. This substance is only slightly soluble in water, is insoluble in alcohol, but readily soluble in salt solution. It is precipitated along with globulin when saline extracts of the kernel are dialyzed (page 341). The gum is readily transformed into sugar by the action of diastase or ptyalin.

The fluid pressed from the finely divided endosperm contains a slight amount of reducing sugar—dextrose. Galactose appears to have been identified also.* Cane-sugar is also present.

The following results were obtained in our determinations of the percentage content of crude fiber in the fresh tissue:†

	1	2	3	4	5	General Average.
Fresh endosperm, *a*	3.96	3.20	2.98	3.40	2.78	
b	4.21	3.80	3.12	3.52	2.98	
Average,	4.08	3.50	3.05	3.46	2.88	3.39

Proteids.—That the meat of the cocoanut contains at most only a very small amount of proteid matter is seen at a glance from the following percentage results for content of nitrogen.‡

Water.	Fatty Acid.	Sodium Oxide (combined).	Sodium Oxide (free).	Other Salts.	Residue.
58.74	32.82	4.26	1.50	2.26	0.42

See also the Dispensatory of the United States of America, 1899: 1619, for references to objectionable chemical qualities of some cocoa-soaps.

* Green: Soluble Ferments and Fermentation, 100. 1899.

† Determinations were made, after the fresh weighed material had been dried and thoroughly extracted with ether, by the method adopted by the Association of Official Agricultural Chemists: Bulletin, Division of Chemistry, U. S. Department of Agriculture, 46: 26.

‡ In these determinations the Kjeldahl method was employed.

	1	2	3	4	5	6	7	General Average.
Fresh endosperm, *a*	0.657	0.734	0.806	0.738	0.766	0.776	0.701	
b					0.740	0.781	0.756	
Average,	0.657	0.734	0.806	0.738	0.753	0.778	0.729	0.742

The fresh endosperm contains an average of 0.74 per cent. of nitrogen which, multiplied by the usual factor, 6.25, would indicate 4.63 per cent. of "albuminoid." Some of this nitrogen, however, is undoubtedly closely associated with the fibrous elements. Much of it probably is in the form of nitrogenous extractive.* Some of the nitrogenous substance is soluble in 95 per cent. alcohol.

The proteid present in the endosperm appears to consist chiefly if not exclusively of globulin and proteose (globulose ?), the globulin predominating in quantity.† We have made several samples of cocoa globulin by the method used by Osborne for the preparation of edestin—in general as follows:‡ The kernel was run through a hashing machine and the finely minced substance freed from fat by repeated extraction in ether for several days. The ether adherent to the tissue was evaporated at room temperature and the ether-free tissue then extracted in 10-per-cent. salt solution for 24–48 hours. The saline extract was then filtered off and globulin thrown from its solution either by the dilution process, by dialyzing for several days in running water, or by treatment with ammonium sulphate to complete or half-saturation. The deposit of globulin resulting thereby always contained an appreciable amount of gummy carbohydrate. The carbohydrate admixture was eliminated by subjecting the deposit to the action of diastase or ptyalin for 24–48 hours, in the presence of thymol at 45° C. in neutral fluid, during which time it was transformed into soluble reducing sugar.§ The globulin residue left behind after this treatment was

* The factor 6.25 is here too large, also, because the proteids present contain about 18 per cent. of nitrogen. See pages 343 and 344. Stutzer found that, of the total nitrogen of cocoa-cakes, from 1.8 to 6.9 per cent. was contained in non-proteid substance. Quoted by Dietrich and König: Zusammensetzung und Verdaulichkeit der Futtermittel; 2: 987, 1380. 1891.

† The amount of nucleoproteid must be very slight.

‡ Osborne: See various papers in the Journal of the American Chemical Society since 1894.

§ Similar difficulty was experienced by Osborne, who got rid of the gum by repeated dialysis and precipitation with ammonium sulphate. Journal of the American Chemical Society, 17: 429, 539. 1895.

further purified by re-solution and re-precipitation. For quantitative analysis some of the final product was washed in water, alcohol and ether, and dried at 100°–105° C. to constant weight.

Sometimes the globulin prepared in this way was both crystalline and amorphous. At other times it was entirely crystalline. Triangular, hexagonal and rhombohedral forms were frequently seen, although octahedra predominated.* The crystals so closely

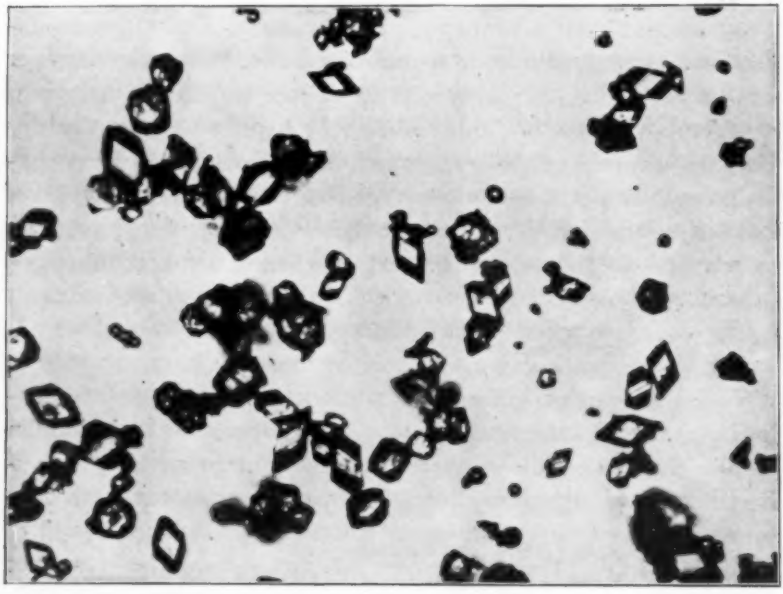

FIG. 4. Crystals of cocoa edestin.

resemble those we have repeatedly made from hempseed and linseed by the same method, and are so like those given by Osborne for edestin,† that we felt satisfied from the beginning our globulin would prove to be of the edestin type. Careful study of the reactions of the substance convinced us of this fact, for it gives all of those attributed to edestin by Osborne.

* The large proportion of gum extracted by the saline solution made it difficult not only to prepare the proteid in pure form but to obtain it quantitatively. Besides, the edestin passed in part into an insoluble modification during the manipulations. An appreciable loss resulted, therefore, in each preparation. We obtained as much as 25 grams of the purified product from the kernels of twelve nuts.

† Osborne: Journal of the American Chemical Society. See also his paper on crystalline vegetable proteids in the American Chemical Journal, **14**: 28. 1893.

On the opposite page we give a microphotographic view of edestin crystals from our second preparation Although not the purest, we have selected this preparation for this purpose because its crystals are mostly rhombohedra. These forms rarely occur in abundance in edestin precipitates, octahedra being more commonly obtained. Most of the larger masses among the crystals shown here are "rounded" octahedra; not in perfect focus because they are thicker than the rhombohedra. The smaller particles consist of globular matter and crystal pieces.

The crystals given in *Fig. 4* were photographed for us by the writer's colleague, Dr. Edward Leaming, who cordially gave us the benefit of his large experience. We wish here again to extend to Dr. Leaming our sincere thanks for his valuable assistance.

That the substance under discussion is edestin is further shown by the results of analysis. We append our results for nitrogen content, as determined by the Kjeldahl method, calculated for ash-free substance:

PERCENTAGE OF NITROGEN IN COCOA EDESTIN

Preparation.	1	2	3	4	5
Analytic results.	17.87 17.77 17.79	17.85 17.96 17.91	17.66 17.69 17.78	18.14 18.21 18.18	18.23 18.20 18.28
Average.	17.81	17.91	17.71	18.18	18.24
Ash.	0.41	0.13	1.12	1.90	1.84

Preparations 1, 2 and 3 contained amorphous material, possibly some of the gummy matter referred to on page 342, in spite of our efforts to completely remove it. Preparations 4 and 5 were obtained from 1 and 3 by further treatment with diastase and by recrystallization by dialysis from 10-per-cent. salt solution. They were practically wholly crystalline.

The above results show that the globulin separated from the cocoanut by the methods here employed is edestin.*

This same proteid of the cocoanut was examined by Ritthausen, † who termed it conglutin without really identifying it with that substance. His analyses gave it a content of nitrogen of 17.87–17.91 per cent. Chittenden and Setchell ‡ referred to it by

* The edestin from barley contains 18.10 per cent. N. That from maize 18.12 per cent.; from rye, 18.19 per cent.; wheat, 18.39 per cent. Osborne: Journal of the American Chemical Society, 17: 547. 1895.

† Ritthausen: Jahresbericht über die Fortschritte der Thier-Chemie, 10: 18. 1880.

‡ Chittenden and Setchell: Quoted by Chittenden, Digestive Proteolysis, 32. 1895.

the name of phytovitellin. The composition they gave for it is in general accord with that of edestin (nitrogen content = 18.40 per cent.), and as they obtained it partly crystallized in octahedra, Osborne * has lately suggested that the substance is edestin. The results we have obtained confirm Osborne's deduction.

The proteose to which we have already alluded was obtained from the globulin filtrate. The latter was freed from traces of globulin by the coagulation method, the hot filtrate evaporated to a small bulk on the water-bath and the proteose precipitated and purified by the usual method. † About four grams were obtainable from fifteen nuts. The product contained both proto and deutero forms. Some heteroproteose was also detected in the products formed on dialysis and a trace of dysprotose was obtained.

The following results for nitrogen content in the ash-free substance were obtained by the Kjeldahl method:

PERCENTAGE OF NITROGEN IN COCOA PROTEOSE

Preparation.	1	2	3	General Average.
Analytic results.	18.67 18.50 18.58	18.48 18.46 18.40	18.57 18.61 18.54	
Average.	18.58	18.45	18.57	18.53
Ash.	1.71	1.08	1.21	1.33

These results differ only slightly from those reported by Chittenden and Setchell.‡ This difference may be explained by the fact that mixtures of proteoses have been analyzed in each case by Chittenden and Setchell, and by us. Their preparation of proteose contained 18.25 per cent. of nitrogen.

In his volume entitled Digestive Proteolysis, Chittenden gives the analytic results for eleven different proteids and the proteoses derived from them (page 67). For seven of these the nitrogen of the corresponding proteose is somewhat higher than that of the original proteid. Analysis of our own preparations has shown the percentage of nitrogen to be greater in the proteose than in the globulin, a result in accord with the majority rule just noted.

* Osborne: Journal of the American Chemical Society, 18: 13. 1896.

† MacDougal: Practical Text-book of Plant Physiology, 164. 1901.

‡ Chittenden and Setchell: Quoted by Chittenden, Digestive Proteolysis, 32. 1895.

There appeared to be only a very slight amount of an albumin in our extracts—a coagulable substance which was not precipitated from its neutral solution when the latter was half-saturated with ammonium sulphate.*

Osborne's methods of extracting glutenin and gliadin † in dilute alkali and acid, and in dilute alcohol, after the removal of globulin, proteose and albumin as above described, gave mere traces of proteid substances in solution, derivatives, doubtless, of the proteids already referred to, which perhaps had not been completely removed from the residual tissue; or possible nucleoproteid.

Peptone could not be detected in any of our extracts.‡

Ash.—Composition is referred to on pages 331 and 335. Qualitatively our results were the same as those there given.

Enzymes.—Water, salt solution and glycerin each failed to extract appreciable quantities of either proteolytic or adipolytic enzymes from the endosperm of the fresh, ungerminated nut, although an active amylolytic ferment was extracted by all of these fluids. The large quantities of fat and fatty acid in the endosperm suggest that an emulsifying ferment may be present. This, however, may be localized in the germ, increasing to physiological quantity and activity only in the process of germination (see page 358). The proteoses present in the endosperm seem to imply the presence of a proteolytic ferment. Possibly, however, the proteoses represent a residue from which the globulin was derived by reverse process.§

We have already referred to the fact that oxidase has been detected in the milk. Traces of it are also contained in the endosperm.

Average Composition.—The average results of our analyses of the endosperm are summarized in the following table, which presents the data obtained for the composition of the fresh tissue and the dry solid matter derived from it (constant weight at 100–105° C.).

* Cohnheim: Chemie der Eiweisskörper, 150. 1900.

† Osborne and Campbell: American Chemical Journal, 15: 392. 1893.

‡ Small quantities of non-proteid nitrogenous substances were detected by Ritthausen: Chemisches Centralblatt, 230. 1880. Compare, also, with recent results respecting proteoses obtained by Bokorny: Chemisches Centralblatt, 1: 1167. 1902.

§ See recent papers in the Zeitschrift für physiologische Chemie by Schulze and Kutscher and their associates.

PERCENTAGE COMPOSITION OF THE ENDOSPERM

Constituents.	Fresh Endosperm.	Dry Endosperm.*
Water.	46.31	
Solids.	53.69	
Inorganic matter.	1.03	1.93
Organic matter.	52.66	98.07
Fat (substance soluble in ether).	37.29	69.45
Crude fiber (cellulose).	3.39	6.31
Proteid (N × 5.5)†	4.08	7.60
Soluble carbohydrate, non-nitrogenous substance, extractive, etc. (by difference).	7.90	14.71
Nitrogen.	0.742	1.382

The previous results obtained by Hammerbacher‡ for the fresh endosperm from nuts of eastern origin were as follows:

Water.	Solids.	Inorganic Matter.	Organic Matter.	Fat.	Crude Fiber.	Proteid.	Non-nitrogenous Extractive.
46.64	53.36	0.97	52.39	35.93	2.91	5.49	8.06

COMPOSITION OF SHELL AND HUSK.—We have already alluded to some of the uses to which the shell and husk of the cocoanut are put by reason of the chemical and physical qualities they possess. Some facts regarding their chemical composition were given in the table on page 335.

The following percentage results of elementary analysis of the powdered shell were obtained by Baumhauer;§ all samples having finally been thoroughly extracted in alcohol and ether, and then dried at 120°–150° C.:

	Cocos nucifera.				*Cocos lapidea.*	
	1. Extracted in boiling water.	2. Extracted in boiling water, dilute alkali and acetic acid.	3. Extracted in boiling water, concentrated alkali and acetic acid.	4. Extracted in alkali and in chlorine water.	5. Same treatment as 1.	6. Same treatment as 4.
C.	52.99	47.19	46.27	43.72	52.20	44.20
H.	5.88	6.09	5.81	6.11	5.80	6.24
Ash.	1.43	——	1.00	——	0.22	0.55

* According to Dietrich and König (König, Menschlichen Nahrungs- und Genussmittel, etc., 1: 612. 1893) the *air-dried* substance contains the following in percentage of the total dry weight:

Total Substance Soluble in Water.	Proteids Soluble in Water.	Sugar (Sugar-Yielding Substance).
15.16	2.27	9.25

† The factor 5.5 is used because the proteids of the endosperm contain 18 per cent. of nitrogen. See references in this connection on page 341, footnote.

‡ Hammerbacher: Landwirtschaftlichen Versuchs-Stationen, etc., 18: 472. 1875.

§ Baumhauer: Pharmaceutisches Centralblatt, 601. 1844.

Nitrogen was detected in small amount in the powders which had not been treated with alkali. The alkaline extracts contained substance, precipitable by acetic acid, with the following percentage composition: From *Cocos nucifera*, C = 50.04, H = 5.81, ash = 4.45; from *Cocos lapidea*, C = 52.15, H = 5.93, Ash = 1.00.

Tromp de Haas and Tollens * were able to show the presence of a large amount of pentosane (xylan) in the endocarp, the powdered material yielding an abundance of xylose on hydration in 4 per cent. sulphuric acid. Mannose was absent from the acid solution from which the xylose had been crystallized. After xylan had been completely removed from the shell-powder by the above method, dextrose was derived from the residue on treatment with sulphuric acid in the usual manner.

In his very complete histological studies of the cocoanut, Winton † recently called attention to the fact that both the husk and shell contain a brown substance which is quickly changed to a reddish color by caustic potash, but is unaffected by alcohol, ether or any of the specific reagents for proteids, fats or resins. He also states that no immediate effect is produced by ferric chloride solution, but on long standing the color is changed to olive green. Winton has pointed out the presence of minute silicious bodies among the fibers of the husk.

Winton, Ogden and Mitchell ‡ give the following percentage data for the composition of the shell:

Water,	7.36	Alcohol extract,	1.12
Solids,	92.64	Reducing matters calculated as	
Organic matter,	99.46	starch,	20.88
Inorganic matter,	0.54	Starch,	0.73
Soluble in water,	0.50	Crude fiber,	56.19
Insoluble in HCl,	0.00	Nitrogen,	0.18
Ether extract,	0.25	Albuminoid (N × 6 25),	1.13
Non-volatile,	0.25	Quercitannic acid,	1.82
Volatile,	0.00		

During germination the shell remains unaltered. The husk soon begins to decay. See page 351.

* Tromp de Haas and Tollens: Chemisches Centralblatt, 2: 359. 1895.

† Winton: American Journal of Science, IV. 12: 265. 1901. Facts are also given regarding the use of powdered cocoa-shell and the husk as adulterants of ground spices.

‡ Winton, Ogden and Mitchell: Report of the Connecticut Agricultural Experiment Station, 2: 210. 1898.

COCOANUT PEARLS.—Within the nut there is occasionally found a small stony substance of a bluish white color, a kind of vegetable bezoar, called in India *calappa*, which is eagerly purchased by the Chinese, who ascribe great virtues to it as a sort of amulet to preserve them from diseases. The cause of its formation in the nut is unknown.

According to Harley and Harley * these pearls, like those of molluscan origin, appear to consist almost entirely of calcium carbonate, with water and organic matter in smaller proportion. Riedel, quoted by Harley and Harley, states that in 1886, while in North Celebes, he found a pearl in the endosperm of the cocoanut. One such a pearl was pear-shaped in form and 28 mm. long.

We are greatly indebted to Dr. D. Morris, Imperial Commissioner of Agriculture for the West Indies, for the following very interesting quotation from a letter to Dr. MacDougal:

"More than two hundred years ago Rumph, an eminent botanist in the East, sent as a present to the Grand Duke of Tuscany a ring in which a cocoanut pearl had been set. Further, Rumph himself described cocoanut pearls in his great work with considerable minuteness and gave illustrations of two of them. One was perfectly round, the other was oval or egg-shaped. * * * Travelers in the Philippine Islands have heard of cocoanut pearls, but seldom or ever have seen them. The natives, it is said, keep "cocoanut stones" as charms against disease and evil spirits. The rajahs, we were told, highly prized them and wore them as precious stones. It was only a few years ago that real cocoanut pearls were at last brought to England. One is now at the Museum at the Royal Gardens at Kew, brought by Dr. Hickson. It is almost egg-shaped, perfectly white, and composed almost entirely of carbonate of lime. It has, in fact, a somewhat similar composition to the pearl of the oyster, and yet there is little doubt it is a purely vegetable product." †

* Harley and Harley: Proceedings of the Royal Society of London, **43**: 464. 1887–88.

† "Besides these cocoanut pearls," quoting further from Dr. Morris' letter to Dr. MacDougal, "Rumph describes what he calls 'Melate' pearls taken from the flowers of a Jasmine; and a 'Champake' pearl taken from the flower of a Michelia. If we had not already seen the pearl of the cocoanut it would have been impossible to believe that there were such things as Jasmine and Michelia pearls * * * Of their composition, mode of occurrence and true nature we have yet to learn." See the article by Harley and Harley referred to above.

See also, on the subject of cocoanut pearls, the Proceedings of the Boston Society of Natural History, 1861 and 1862; The Tropical Agriculturalist, 1887; Nature, 1887.

III. CHANGES IN THE COCOANUT DURING GERMINATION

The nuts for our studies of the changes occurring during germination were obtained fresh, fully developed and with their husks still on them, directly from Jamaica. Immediately after their arrival at the New York Botanical Garden they were imbedded in earth until they were nearly covered. The earth was kept saturated with water and a tropical temperature was maintained. These conditions closely approximated those attending normal germination.

MORPHOLOGICAL CHANGES.—Nearly four months elapsed before the shoots began to appear through the husks, the fibers of the husk having been pressed aside in their upward progress. At this stage the stem of the shoot was an inch or more in diameter at the "root-crown," sharply tapering toward the point of penetration at the surface of the husk. As the growth proceeded it seemed to gradually become more and more rapid, and by the end of a year the plants had attained the height of two or three feet, with a stem about an inch in diameter throughout most of its length. By this time the part of the husk under the earth had decayed considerally; it became softer and more porous, and several stout roots had developed through it and penetrated the soil to the depth of a foot or more.*

The appearance of the nuts and their plants at this period of their growth is shown in the cut on page 350. Unless otherwise stated, the chemical analyses reported farther on were made of the parts at this stage of their development.

It may not be amiss, in describing the morphological changes induced in the nut during the process of germination, to also briefly review, at the same time, the more important facts regarding structure of the nut as it exists in the ungerminated condition.

The entire fruit is, strictly speaking, intermediate between a nut and a drupe — a "drupaceous nut." The outer covering,

* For facts regarding germination and cultivation see Bailey: Cyclopedia of American Horticulture, 1: 341–343. 1900. Also, Wittmack, L.: Die Keimung der Cocosnuss. Ber. d. deut. bot. Ges. 14: 145. 1896.

FIG. 5. Germinating cocoanut at the end of a year, showing plumule and roots, with husk little altered except where it was in contact with the earth.

usually removed before the nut appears upon the market, is a thick fibrous layer comprising the exocarp, the epicarp consisting of a smooth, thin, tough coat of a brownish or grayish color. (See pp. 323 and 324). The endocarp, or what is commonly known as the shell of the nut, is composed of three carpels whose lines of fusion are always apparent. The nut lies in the husk with the end containing the "eyes" toward the pedicel. Each carpel contains an "eye," so-called, and under one of these three eyes, the

softest, is the germ imbedded in the endosperm. The fertile carpel may be recognized from the fact that it has the greatest degree of divergence between the longitudinal fusion lines of the carpels. The true integuments of the ovule are reduced to a thin brown coat closely adhering to the abundant endosperm.

The embryo is a cylindrical body about 8 mm. in length lying below one of the natural openings of the endocarp and in a line perpendicular to the exterior surface of the endosperm. When germination begins the embryo elongates and, having pushed through its thin coverings, begins to enlarge at both ends. From the outer end arises the plumule and the roots; the inner end is an extension of the true cotyledon and is developed into a special absorbing organ. See *pl. 19*.

The absorbing organ is of a soft spongy texture and all through it are the ramifications of vascular strands which converge to the narrow "neck," which connects the absorbing tissue with the stem. The cotyledon, and by this term, hereafter, we shall mean the part of that structure specialized for absorption, can attack only the part of the endosperm to which it is contiguous. In the earlier stages of growth this absorption is confined to the part nearest the young shoot, which we may hereafter refer to as the proximal end of the nut. Finally, however, the cotyledon fills the entire cavity of the nut and somewhat thins the endosperm distally, also.

The milk may persist in the nut until the cotyledon has almost filled the cavity. After germination has proceeded for some time the milk becomes insipid to the taste, and contains fragments of cellulose and large drops of floating fat. In nuts in which germination has continued for a year the cotyledon has entirely filled the cavity, but usually there is still left a third to a half of the endosperm undigested. This residual portion in normal cases is little affected, except that it is softened superficially, and to the taste suggests nothing different from the meat of the ordinary ungerminated nut.

In its natural development the roots of the plant soon take firm hold of the soil and, long before the endosperm is completely absorbed, junction between the shoot and the absorbing organ is broken, the husk decays and the plant enters an inde-

pendent career. Neither the husk nor the shell appears to serve any other than passive mechanical function, and only the constituents of the endosperm and milk, so far as the nut is concerned, nourish the young plant before it finds in the soil the elements provided there in abundance for its growth to maturity.*

In our microscopic studies, particularly of the cotyledon, pieces of the fresh part were "fixed" in a mixture of glacial acetic acid (1/3) and 70% alcohol (2/3). After remaining in this fluid for a few hours the pieces were transferred to 70% alcohol and later to 85% alcohol, in which they were kept. Sections were cut with a razor and mounted in glycerin. Treated with iodine, such sections of the cotyledon showed an abundance of starch in all cells except those of the outermost layer or epidermis. This outer layer stained yellow with iodine. That it contained an abundance of oil was shown by its deep black reaction with osmic acid. Large globules of oil are, however, distinctly visible in the epidermis under the microscope without the aid of osmic acid. Oil may also be found in the subepidermal layers, but it rapidly diminishes in quantity as the distance from the outside increases and as the starchy deposit accumulates. Needle-like crystals may be very readily found in the epidermal cells. These resemble crystals of tripalmitin, but the fact that so much oil appears in globules, and that the breaking down of fats must occur to a large extent in these cells, would suggest that they are palmitic acid rather than the fat itself.

The above facts make it appear that the starch is formed indirectly at least from the oil.† See references under enzymes, pages 345 and 358.

See *pl. 19* for drawings of parts mentioned above.

CHEMICAL CHANGES.—The following summary gives briefly the effects of germination on the individual nuts examined:

I. *Not Analyzed.*—A. Development had proceeded for nearly six months. The plumule protruded six inches above the husk. Roots had developed through the husk—two were about a quarter of an inch in diameter. The stem was very thick at the "root-

* Note references on page 357 to the functions of the husk in holding water and possibly furnishing nutrient matter in its decay.

† Ebermayer: Physiologische Chemie der Pflanzen, 347. 1882.

crown"; sharply tapered to the point of surface penetration. The fibers about the stem were tightly pressed together. The neck of the absorbing organ was very woody and fibrous in character. Absorption of the endosperm at the proximal end was quite marked; distal portion undiminished. Milk cavity largely filled by the absorbing organ. A small space at the distal end remained, containing viscid white material full of large oil globules; quantity less than 10 c.c.—doubtless concentrated milk. It was strongly acid in reaction from acid phosphate, reduced Fehling's solution, gave only a faint biuret reaction and was free from starch. The inner surface of the endosperm in the distal portion was soft, having the consistency of lard.

The weight of the whole shoot, minus the roots, in the fresh condition was 28.1 grams. Dry, the weight was 4.25 grams or 15.1 per cent. of the fresh substance, indicating a presence of 84.9 per cent. of water in the original plant.

B. This nut, although germinating for the same period of time, was not quite as far advanced as the previous one, having shoots that were just emerging from the husk. The stem was thicker, however. In most respects its internal condition was exactly the same as that of the first. The fluid in the distal cavity was less in quantity, not as turbid, contained less oil—otherwise was the same as that of the previous nut.

The weight of the entire plumule was 38.8 grams. Dried, it weighed 5.75 grams. Thus it contained 14.8 per cent. of solid matter and 85.2 per cent. of water.

II. *Analyzed.*—1. Growth continued for eight months. The cotyledon entirely filled the cavity. About half of the endosperm was absorbed; practically all of that proximally except a thin layer. The distal residue of endosperm appeared to be normal in taste and appearance except on the surface, where the soft layer previously referred to—one fourth the entire thickness—could again be seen. The outer surface of the cotyledon, that part in contact with the endosperm, was much corrugated; the whole organ, solid but spongy, sweet and agreeable to the taste, pyriform. In the tables on page 354 and 355 the results of our analyses for this nut are indicated by the numeral 1.

GENERAL COMPOSITION OF THE PARTS OF THE GERMINATED COCOANUT

Parts of the Nut and its Plant.		Percentage of fresh Tissue.				Percentage of Solids.	
		Water.	Solid Matter.				
			Total.	Organic.	Inorganic.	Organic Matter.	Inorganic Matter.
I. *Cotyledon.*							
A. Central, vascular portion:	*a*—1	89.10	10.90	99.14	0.86	92.07	7.93
" " "	*b*—1	87.71	12.29	99.10	0.90	92.25	7.75
" " "	*c*—2	91.62	8.38	99.00	1.00	88.10	11.90
" " "	*d*—2	91.41	8.59	99.11	0.89	89.71	10.29
" " "	*e*—3	88.99	11.01	99.20	0.80	92.77	7.23
Central, between center and surface:	*f*—3	86.07	13.93	98.94	1.06	92.36	7.64
Average.		**89.15**	**10.85**	**99.08**	**0.92**	**91.21**	**8.79**
B. Outer, corrugated portion:	*a*—1	84.95	15.05	98.69	1.31	91.30	8.70
" " "	*b*—2	82.79	17.21	98.93	1.07	93.85	6.15
" " "	*c*—3	80.83	19.17	98.26	1.74	90.93	9.07
Outer portion—neck:	*d*—3	78.98	21.02	98.58	1.42	93.24	6.76
Average.		**81.89**	**18.11**	**98.62**	**1.38**	**92.33**	**7.67**
II. *Residual endosperm.*							
C. Proximal portions after much absorption:	*a*—2	19.09	80.91	99.13	0.87	98.92	1.08
	b—3	23.42	76.58	99.16	0.84	98.90	1.10
Average.		**21.25**	**78.75**	**99.15**	**0.85**	**98.91**	**1.09**
D. Medial portions:	*a*—1	31.65	68.35	99.03	0.97	98.58	1.42
	b—1	30.36	69.64	99.06	0.94	98.65	1.35
	c—2	28.68	71.32	99.25	0.75	98.95	1.05
	d—3	25.77	74.23	99.23	0.77	98.96	1.04
Average.		**29.12**	**70.88**	**99.14**	**0.86**	**98.78**	**1.22**
E. Distal, normal portion:	*a*—3	46.08	53.92	99.02	0.98	98.12	1.82
III. *Stem of the plant.*							
F. Base, "root crown," with petioles at lowest parts:	*a*—1	86.21	13.79	98.95	1.05	92.37	7.63
	b—1	86.51	13.49	98.70	1.30	90.38	9.62
	c—2	85.15	14.85	98.84	1.16	92.06	7.94
	d—3	84.31	15.69	98.68	1.32	91.60	8.40
Average.		**85.55**	**14.45**	**98.79**	**1.21**	**91.60**	**8.40**
G. Parts above the base, with more petioles:	*a*—2	82.47	17.53	98.80	1.20	93.20	6.08
	b—3	79.87	20.13				
Average.		**81.17**	**18.83**				
IV. *Petioles.*							
H. Alone, or with young leaves:	*a*—1	83.63	16.37	98.57	1.43	91.27	8.73
	b—1	82.55	17.45	98.63	1.37	92.15	7.85
	c—3	82.13	17.87	98.75	1.25	93.01	6.99
	d—3	82.17	17.83	98.63	1.37	92.34	7.66
Average.		**82.62**	**17.38**	**98.65**	**1.35**	**92.19**	**7.81**

GENERAL COMPOSITION OF THE PARTS OF THE GERMINATED COCOANUT.—*Continued*

Parts of the Nut and its Plant.		Percentage of fresh Tissue.				Percentage of Solids.	
		Water.	Solid Matter.			Organic Matter.	Inorganic Matter.
			Total.	Organic.	Inorganic.		
V. *Leaves.*							
I. Mature or nearly so:	*a*—1	74.66	25.34	98.35	1.65	93.49	6.51
	b—1	71.99	28.01	98.10	1.90	93.20	6.80
	c—2	72.60	27.40	98.34	1.66	93.93	6.07
	d—2	72.51	27.49	98.41	1.59	94.19	5.81
	e—3	68.45	31.55	97.96	2.04	93.52	6.48
	f—3	70.65	29.35	98.39	1.61	94.52	5.48
Average.		71.81	28.19	98.26	1.74	93.81	6.19
J. Very youngest:	*a*—3	87.22	12.78	98.50	1.50	86.67	13.33
VI. *Roots.*							
K. Short, not developed outside of husk, with soft tips:	*a*—1	87.08	12.92	98.46	1.54	88.09	11.91
	b—2	89 89	10.11	98.67	1.33	86.89	13.11
	c—2	86.41	13.59	98.43	1.57	88.44	11.56
	d—3	87.46	12.54	98.83	1.17	90.70	9.30
Average.		87.71	12.29	98.60	1.40	88.53	11.47
L. Parts of longer roots, taken near the stem:	*a*—1	77.92	22.08	98.80	1.20	94.59	5.41
	b—2	82.65	17.35	98.85	1.15	93.34	6.66
	c—3	81.09	18.91	98.50	1.50	92.09	7.91
	d—3	79.47	20.53	98.77	1.23	94.00	6.00
Average.		80.28	19.72	98.73	1.27	93.51	6.49
M. Parts of longer roots, taken outside the husk:	*a*—1	81.70	18.30	97.94	2.06	88.76	11.24
	b—1	84.64	15.36	98.47	1.53	90.05	9.95
	c—2	82.79	17.21	98.40	1.60	90.74	9.26
Average.		83.04	16.96	98.27	1.73	89.85	10.15

2. This nut represented germination after ten months and was essentially like the preceding in all respects. The roots were thicker and a number of good sized ones had not yet proceeded through the husk. Their ends were soft and watery, rounded and blunt. Analyses of this nut are referred to in the tables on pages 354–355 by the numeral 2.

3. Essentially the same as No. 2, both in stage of development and conditions of parts, although the time of germination was about two months longer. Analyses of the parts of this nut are referred to in the tables on pages 354–355 by the numeral 3.

4. This nut had germinated for just about a year. The follow-

ing weights of the fresh parts were very carefully taken; the data for nitrogen were determined by the Kjeldahl method.*

	Weight in Grams.	Percentage of Total Weight.	Percentage of Nitrogen.
Cotyledon,	196	28.1	
Central part,			0.14
Cortical layer,			0.31
Endosperm,	155	22.2	
Distal portion,			0 65
Proximal portion,			0.93
Shell,	161	23.0	
Stem,	16	2.3	
Lower part,			0.70
"Root crown,"			0.53
Roots,	41	5.9	
Inside of husk,			0.27
Outside of husk,			0.54
Petioles and young leaves,	58	8.3	0.29
Petioles,			0.39
Old leaves and petioles,	71	10.2	0 45
TOTAL WEIGHT,	698		
Shell and contents,	512	73.4	
Whole plant,	186	26.6	
Cotyledon and endosperm,	351	50.3	

The tables on pages 354–355 give all our results for general composition of the parts of the germinated nut.† Numerous deductions may be drawn from these results, as to growth and metabolism.

The central part of the cotyledon, with its vascular network, contains more water and less solid matter than any other part of the germinated nut. The proportion of solid substance in it increases toward the corrugated epithelium, being greatest in the "neck," where the structure is fibrous and woody.

That the absorbing organ completely takes up the milk is very evident from the way it fills the cavity and from its own composition, but it is likewise apparent from our results that water is also with-

* The husk was not weighed because it was decayed underneath and water-logged. Nitrogen was not determined in the shell because its substance remains unaltered during germination.

† The methods of determination were the same as those used previously. The roots, outside of the husk, which had been in the wet soil, were hurriedly rinsed with water to remove inorganic matter then wiped dry with a towel and at once cut into thin cross sections for analysis.

drawn from the residual endosperm, this absorption being greatest at the proximal end of the nut, where absorption was begun in the first place, and least at the distal end, where it had hardly commenced. The roots also are seen to have absorbed considerable moisture.

The lowest part of the stem contains almost as little solid matter and is nearly as watery as the cotyledon. The percentage of water in the stem diminishes as the distance away from the "root crown" increases. The watery condition of the lower part of the stem is increased, doubtless, by the fact that the surrounding husk is impregnated with water, thus favoring direct absorption by osmosis and at the same time preventing evaporation from the surface of the growing tissue.

The amount of solid matter in the petioles is also comparatively slight, little more than in the lower part of the stem. In the leaves the water is greatest in the youngest, as would be expected; least in the oldest — those most exposed to the air.

The roots at the tips are soft and watery, but the older they become the more solid matter they develop and the more woody material they accumulate.

In the distribution of the inorganic matter in the fresh parts it is noticeable that the proportion of saline substance increases with a decrease of water and *vice versa*, as in the cotyledon, in the residual endosperm and throughout the plumule. This condition is such as might be expected. The relation of the inorganic to the organic matter in each part, however, is variable. The substance of the cotyledon and the stem contains a greater proportion of salts than that of the endosperm and the leaves, the roots likewise holding a fairly large amount of saline matter. The substance of the endosperm contains least of all, from which fact it is quite clear that the inorganic matter of the plumule has been absorbed, not only by the cotyledon from the milk, but also by the roots from the fluid in the husk and the surrounding earth.

At the beginning of germination the inorganic matter and water of the milk are doubtless sufficient for the changes that occur, the organic matter coming chiefly from the endosperm. Some time before the cotyledon fills the milk cavity and completely absorbs the milk, the roots have begun to take water and inorganic

matter from the fluid in the husk—possibly also organic substance from the disintegrating husk fibers—and thus they absorb new nourishment from a large supply. Growth of the plumule is consequently favored. The plumule soon reaches such a height and development as to enable it to make increasing contributions to the plant metabolism from the gaseous products the air affords. By this time the whole growth has become practically independent of the reserve material of the seed.

ENZYMES.—We made only a few preliminary studies of enzyme distribution. Extracts were made in water, dilute salt solution and glycerin. The indicators used in nearly all the experiments were prepared from the materials in the nut itself.

The extracts of the cotyledon were acid to litmus (phosphates), though, as indicated by lacmoid, they contained no free acid. Diastatic ferment was found to be distributed in abundance in all parts of the cotyledon. Oxidase was also present. Only the very slightest proteolytic action was manifested by the cotyledon extracts, even when they were obtained in particularly concentrated form. In some experiments the results were entirely negative, however. Cellulose-dissolving and fat-splitting enzymes were not detected in either the cotyledon or the residual endosperm, although we cannot be sure that in our few experiments they have not escaped us.* Germination progresses so slowly that possibly some of the enzymes are present in only very minute quantity at any one time—in such amount, perhaps, as to be undiscoverable by the methods commonly employed for ferment detection. We did not examine the parts of the plumule in this connection.

At this point, before we were able to come to any very definite conclusions as to the enzymes present and before we could determine the distribution of proteids, fats, carbohydrates, etc., in the parts of the plant, we were obliged to discontinue our work. The writer hopes to extend these experiments on the germinated cocoanut to a consideration of related problems of nutrition.

* See our references to enzymes on page 345. Lipase seems to have been found in the germinating cocoanut by Lumia: Jahresbericht über die Fortschritte der Thier-Chemie, **28**: 724. 1898.

Explanation of Plate 19

FIG. 1. An end view of the cocoanut, without its husk, showing the three carpels and the "eyes." The fertile carpel is the one included in the largest angle.

FIG. 2. A sectional view through the end of an ungerminated nut, with its husk removed, showing the form and location of the germ imbedded in the endosperm (under the micropyle). The shell is indicated by the heavy outline.

FIG. 3. Another sectional view similar to that of Fig. 2 showing development of the absorbing organ after germination had proceeded for a few weeks. The incipient stem and roots are to be seen. The cotyledon has enlarged within and without the shell.

FIG. 4. A longitudinal section through the whole nut somewhat to the side of the median line. It shows the nut imbedded in its fibrous husk and the conditions found after germination had gone on for about five months. The absorbing organ has filled about two thirds of the cavity of the nut but has absorbed comparatively little of the endosperm. The stem has proceeded upward through the husk, the roots downward through the husk into the soil. The leaves have been cut off above the husk. (See page 350 for appearance of full plumule.)

FIG. 5. A section through the layer of the cotyledon normally in contact with endosperm, showing the corrugated, villiform arrangement of the absorbing epithelium. This section having been treated with osmic acid shows the localization of the fat globules.

FIG. 6. A section through that part of the cotyledon given in Fig. 5. This section, treated with iodine, shows the localization of starch.

FIG. 7. A few cells from the absorbing epithelium of the cotyledon after enlargement. This figure shows the large clear oil globules and the darkly staining starch grains in the subepidermal cells. The crystals seen in most of the cells appear to consist of fatty acid, possibly palmitic.

FIG. 8. Enlarged starch granules from subepidermal cells.

Some Observations on Transpiration

CARLTON C. CURTIS

Variations in the rate of transpiration have been observed almost from the beginning of physiological research. These irregularities present a most puzzling problem since they appear in the results obtained by any method that may be employed to demonstrate the phenomena of transpiration and notwithstanding the fact that the external conditions may be apparently uniform and constant, I have been interested to take note of the records that have been made from year to year, when this subject comes up for experimentation in the laboratory with a view to determine whether there is any rhythm to be found in the fluctuations, and if so, whether this is related to the tension of fluids in the stem. In other words, to find out in what degree transpiration might be connected with the vital phenomena of the plant.

The table on the following page illustrates the character of the fluctuations and these examples are presented since they were obtained under as constant conditions as could be expected with natural light.

The amount of transpiration is expressed in milligrams obtained by hourly weighings beginning in the morning and running through the day, and below each series is given the changes of temperature and humidity while on the right hand of the table is noted the character of the day.

The intensity of the light may account in a certain degree for the maxima of the curves coming near the middle of the day although there was no apparent variation in the amount of illumination at that time of day. However, there are minor fluctuations in the curves quite independent of the slight variations of the climatic conditions and the light intensities and they are as likely to be at variance with any perceptible changes as in keeping with them. These irregularities may result in the rise or fall of the rate for a short period or again they may extend over longer periods. They are quite as appearent in the consecutive readings of potometers and especially in the device of Darwin's where a shoot

I. TRANSPIRATION CURVES IN DAYLIGHT

ABUTILON THOMPSONI

6 A. M.	7	8	9	10	11	12	1 P. M.	2	3	4	5	6	
160	243	316	366	504	602	643	715	686	636	646	641	304	Cloudy with
						Temperature							
24				25			25.5		25		24		rain from 11
						Hygrometer							
24				25			21		23		23		to 5.

KALANCHOE GLAUCESCENS

12	22	28	32	36	48	64	57	39	34	36	26	18	Cloudy.
						Temperature							
26						27		28			27		
						Hygrometer							
30						28		26			28		

ANTHOLIZA AETHIOPICA

91	100	98	102	118	127	173	180	166	133	124	132	119	Snowing.
						Temperature							
20					21	22				21		19	
						Hygrometer							
33					30	30				34		36	

ACALYPHA HISPIDA

59	56	52	96	243	220	304	328	354	168	108	84	108	Raining,

KLEINIA FICOIDES

8	6	7	10	20	24	39	58	73	62	29	27	20	
						Temperature							
19		19			20		21				21		cl'ring 3.30
						Hygrometer							
55		54			52		50				48		but cloudy.

STACHYS GRANDIFLORA

26	30	40	74	67	84	120	115	99	99	60	36	39	Cloudy.
						Temperature							
17							17.5				17.5		
						Hygrometer							
42				44			43				46		

FICUS INFLECTA

81	91	136	82	63	195	244	229	239	150	62	57	50	Very dark
						Temperature							
19				20							21		in forenoon
						Hygrometer							
42				38							36		becoming foggy.

is sealed to a test-tube and the loss in weight is viewed with a horizontal microscope or in Gardner's experiment where the transpiration stream of a small shoot is viewed under a microscope. In both of these latter cases the transpiration rate can be examined in short intervals of time and we have a magnified view, so to speak, of the process. In all these methods the irregularity of the rate is the striking phenomenon. It is ever fluctuating and without apparent reason. It is exceptional to find consecutive readings that show a fixed ratio of increase or decrease. In the above table while the hourly weighings furnish singular irregularities they give an imperfect idea of the endless series of changes that are constantly going on.

In the curve found for *Abutilon*, the acceleration though continuing for eight hours (a very exceptional curve) increases very irregularly, *i. e.*, by 83 mg. 73, 50, 38, 98, 41, 72, and then declines by 29, 50, rises again by 11 and finally declines by 5.337—the last evidently a light effect. In the case of *Kleinia* and *Acalypha* an irregular decline follows for three hours when the rate for *Kleinia* accelerates for six hours and then declines, while in the case of *Acalypha* there is a rise for two hours followed by a decline for one hour, then a rise for three hours, then a decline for three hours, then a rise for one hour. The succeeding hour, not given in the table, showed a further decline, *i. e.*, 96 but still in excess of the rate at 5 o'clock. I was able to verify the character of these fluctuations during the summer of 1901 at the N. Y. Botanical Garden and it gives me pleasure to acknowledge the facilities for conducting the work that were placed at my disposal.

It would seem that these variations can only very indirectly be connected with external conditions and the facts would appear to warrant the conclusion that the phenomena here recorded are the expression of the vital processes at work in the plant. It should be said that in all the experiments recorded in this paper that care was taken to select thrifty potted plants and the jars were placed in large tin cans, the mouths being closed with tin covers and sealed with beeswax mixture after the manner suggested by Darwin. In this way a considerable volume of air was at the disposal of the roots and would serve to keep the plant in normal condition for some time. It was necessary to make the

weighings exactly at the end of the hour if the various measurements were to be of any value. It is apparent how imperfect a knowledge of the transpiration rate or how misleading may be the results when observations are taken at long or irregular intervals or for a short period and from such data drawing conclusions as to the rate.

For the purpose of comparison a number of experiments were conducted under more uniform conditions. The records found in Table II. were obtained in the dark room where the plants were exposed to an electric light of 900 candle power hung at a distance of 4 m. from the balance. The dark room was sufficiently light-tight to permit the handling of the most sensitive photographic plates without injury. When necessary the humidity was controlled in a degree by sprinkling the floor and the temperature rarely varied more than one degree. In this and the preceding table where the record of two plants are given at the same time two separate balances were used to avoid a possible error due to distributing the plants in moving them. Baranetsky's contention on this point has something of merit. Certainly with the most careful manipulation the operator runs a very considerable risk of disturbing the delicate balance in the plant and in a continued series of observations it is at least questionable whether the results obtained in this manner may always be relied upon. The plants in these experiments were usually placed in the dark room over night or for two or three hours before using. This permitted an adjustment to the conditions obtaining in the room and eliminated such after effects as have been noted by Schwendener and Sorauer. Buds and young leaves were cut off in many of the cases cited about one week before the experiment; in other instances such parts were sealed with a mixture of beeswax, tallow and linseed oil and then bound with sheet rubber. The interesting results obtained by Hoehnel on the relative transpiration rate of young and old leaves and similarly by Wiesner on the transpiration of developing stems and also of Sorauer on the relation of the formation of chlorophyll to the transpiration, renders it necessary in arriving at any conclusion as to what the plant is really doing to exclude such factors as may introduce variations that would furnish misleading results

or more probably quite nullify the value of the observations. As will be seen the measurements show an unmistakable curve characterized by minor fluctuations but demonstrating a grand curve with a maximum in the forenoon or near the middle of the day. In several instances I have noticed that transpiration was more active earlier in the day than was found in the first table. This may be due to the fact that the electric current was not turned on till 7 o'clock and the escape of the excess of intercellular vapor in the following hours overbalanced the normal transpiration under the feeble illumination. I regret that it was impossible to secure the curve for 24 hours under constant illumination. However, it will be seen that the curves for 12 hours bear a resemblance to the irregular daily curve of growth determined by Sachs. The absorption curves given by Vesquè, also the curves of fluid tensions in the stem determined by Detmer and the periodicity of the exudation of fluids from cut stems, all show variations in keeping with the records set forth in Table II. It is interesting to note that these curves correspond in the main with those found in Table I. and show the same erratic character. Every plant appears to possess an individuality that becomes evident in these continued irregularities. In fact it has never been my experience to secure two measurements from the same plant that showed similar fluctuations, although special attention was given to placing them under the same conditions for two or more days between the tests.

While there may not necessarily be a constant relation between absorption, exudation and tension of fluids and the phenomena of growth, nevertheless, analogy and the general harmonizing of the ratios of these various rhythms with the curves of transpiration would seem to point unmistakably to the dependence of the latter process upon the vital activities of the plant. The marked irregularities in the rate are of special significance in this regard. As had been said they cannot be connected with any minor variations of the light, temperature or humidity—at least this statement would apply to many of the experiments where the instruments would show no appreciable fluctuations for hours at a time. Furthermore these results would naturally be expected where we consider Pfeffer's work on the energy of the cell. So many factors enter that the secretion and excretion are constantly

II. TRANSPIRATION CURVES UNDER ELECTRIC ILLUMINATION

EUONYMUS JAPONICUS

8 A.M.	9	10	11	12	1 P.M.	2	3	4	5	6	7
38	67	105	167	116	82	110	108	92	89	72	

PELARGONIUM ZONALE

53	42	54	56	66	49	48	52	46	40	42	34

Temperature

25		26	27			26				25	

Hygrometer

28		30	28			31				30	

GARDENIA JASMINOIDES

27	36	57	60	65	60	63	55	33	38		

JUSTICIA ELEGANS

216	214	248	235	269	270	210	228	214	150		

Temperature

20		20.5				21		20.5			

Hygrometer

32		30				29		30			

FUCHSIA SPECIOSA

45	40	42	45	53	52	44	45	46	42		

AUCUBA JAPONICA

25	48	67	40	60	50	45	38	30	27		

Temperature.

22			21.5		22		22				

Hygrometer

37			36		36		38				

ACALYPHA HISPIDA

176	182	184	210	194	182	176	177	147	141	138	

Temperature

23				23					23.5		

Hygrometer

51				50					52		

FICUS ELASTICA

126	134	143	170	145	116	106	98	110	93		

Temperature

20		21				22					

Hygrometer

46		46		48		47					

SPARMANNIA

7	24	23	26	31	26	24	24	12	16		

Temperature

24.5				25				24.5			

Hygrometer

37				35				35			

subject to variation. Saturation, tension of gas, salts, food contents, metabolic processes, conditions of growth, all, acting independently of outward conditions, have in a degree a controlling influence on the cell activity and the expression of this complex interaction is found in the fluctuations. It is not intended to imply that transpiration is a purely physiological phenomena. The position of Nägeli is the only rational one—all physiological processes are dependent upon chemical and physical laws and every vital phenomenon goes on in accordance with these laws. This statement of Nägeli's made in 1861 would almost seem prophetic in the light of the knowledge on this subject of vital phenomena held to-day. We are accustomed to look upon the phenomena of transpiration as a purely physical process, largely, no doubt, because it is so intimately associated with the factors that govern evaporation. However, in this consideration we overlook the fundamental character of the physiological processes involved in transpiration and that are of the highest importance in growth, development and gaseous exchange. And it may be pointed out that the manner of action of light upon transpiration is by no means a settled problem, aside from the fact that it is intimately associated with the activities of the cell. Certainly the behavior of plants in light and darkness and the reaction of etiolated, chlorophylless and green plants to light would be difficult to explain on a purely physical basis. Again the after effects attending variations of illumination indicate interactions of a physiological character. If the vaporization of water in the plant is of a mechanical nature, having for its purpose the diffusion of the meager supply of salts required by the plants, then the process is not in keeping with the exceptional economy illustrated in the activities of the plant. It appears as rather remarkable when we consider the devices for the distribution of the slowly diffusing organized products, that the plant never hit upon an adaptation that would provide it with this relatively minute quantity of salts without putting it to the expenditure of so much energy. This supposition certainly ranks transpiration as perhaps the most wasteful operation in the vegetable kingdom.

The most variable factor in the external conditions of the experiments mentioned above was the variation in the percentage of

moisture. The temperature would remain constant for long periods but the humidity was subject to more considerable variations. I was interested to observe what results would follow changes of humidity. A rise of a few per cent. had no effect that could with certainty be recognized. The following figures will illustrate the result when the humidity was changed at 11 o'clock from 36 to 44.

III. EFFECT OF MOISTURE

	10 A. M.	11	12	1	2	Temp.	Hygrm.	Time.
Aucuba Japonica,	167	164	136	167	108	18.5	37	10
Richardia Africana,	142	138	135	112	106		36	11
Opuntia camnessa,	5	7	0	4	3		44	12
Begonia metalica,	98	117	93	80	70	19	44	1
Cycas revoluta,	70	70	37	29	20		44	2

The result of this very considerable change is unmistakable and is apparent in the increased irregularities of the curve. The variation in *Opuntia* is in keeping with what might be expected from a plant of so pronounced adaptive character. It should be stated, however, that the curves of several cacti, obtained under fairly uniform conditions, were very uneven. These results are such as to warrant the conclusion that no serious error was being introduced through the fluctuations of the hmidity.

A few measurements are given in Table IV., of the transpiration of plants in the dark. Occasionally there is apparent a rhythm corresponding to the daily periodicity, but on the other hand it not unfrequently happens that there may be an irregular decline from the start or the curve may be characterized by a rise or fall without reference to the period of the day. I have noticed on several occasions that pronounced maxima may be found early in the morning—between 5 and 9 o'clock.

Manifestly little importance is to be attached to the results obtained under such conditions inasmuch as they represent the work performed under practically pathological conditions and the results throw little light upon the real action of the plant. While the rate becomes more uniform as Kohl and Wiesner have pointed out there is also to be noted a marked decline and the plant is less responsive to the stimuli of light, all the phenomena, in fact, point to a cessation of the activities. The tissues become congested and it is apparent

IV. ABSENCE OF LIGHT

	6 A. M.	7	8	9	10	11	12	1 P. M.	2	3	4	5	6
FICUS INFLECTA,	58	71	64	52	53	96	70	110	68	54	56	48	
Temperature,		17.5		18					18.5				
Hygrometer,		51		50					49				
FICUS ELASTICA,		286	255	247	280	294	270	265	266	247	223	203	166
		17.5					17.5		18			18	
		40					41		40			39	
GARDENIA JASMINOIDES,		32	34	30	49	48	46	40	44	38	32	36	34
Temperature,		19.5		20		19.5		20.5				21	
Hygrometer,		37		37		38		37				36	
NERIUM OLEANDER,		53	60	57	59	83	75	64	62	56	45	40	
Temperature,		20	21				21				21		
Hygrometer,		46	45				44				44		
ACALYPHA HISPIDA,		90	88	84	68	76	85	93	119	86	78	80	84
Temperature,		18		19				20			20		
Hygrometer,		38		37				36			36		
JUSTICIA ELEGANS,	210	190	164	135	198	167	170	195	166	174	192	213	184
Temperature,		18		19					195				
Hygrometer,		36		36					33				

that this must lead to a disarrangement of the operation of the vital processes. I was particularly interested to note that the leaves in many cases decidedly changed their positions. They often appeared to flag as if from the loss of water. They were, however, perfectly rigid and the changed turgor tensions had caused the curvature of the petioles. In other instances the edges of the leaf turned strongly upwards. This was particularly the case in *Begonia* while in *Fuchsia* many of the leaves bent down, forming a half circle and in so rigid a leaf as that of *Ficus* a lateral twisting of the leaves was sometimes to be seen.

The amount of water transpired is rather surprising in view of the fact that we usually consider the stomata as closed in the dark. Very few authors have maintained that the contrary condition is the case. Considering the ratios that have been found by Garreau and others between the dorsal and ventral surfaces of leaves it appears impossible that the cuticular transpiration could equal the volume recorded in the table. Only one instance has been noticed where the plant seemed to have the power of closing the stomata. In the case of *Cycas revoluta* brought into the dark room at 7.45 a. m. weighings were made hourly from 12.45 on with the following results: loss of 7 mg., 25, then gained for four hours 3, 2, 3, 2, loss 2, 7, gain 2, 4, 2, 0, 2. Temp. 21 to 19, Hygrm. 32 to

36. Six days later the same plant, having been returned to the green house, gave from 10.10 a. m. these readings: gain 0, 6, 2, loss 4, 7, 4, 8. Temp. 22 to 23.5, Hygrm. 32 to 30. The changes in the temperature and humidity were not corollated with the fluctuations. The gain in weight may be due to a precipitation similar to that noted by Volken in certain plants.

I was interested to make some further investigations upon the relations between cuticular and intracellular transpiration. The results will be found in Table V. The stems and petioles of plants from which the immature leaves had been removed a week previous were carefully sealed with wax mixture and the transpiration rate determined in the dark for three hours. Then the under surface of the leaves were rubbed with the wax so as to thoroughly plug the stomata and then coated with a further coat of the wax. The figures indicate that the stomata were closed. This wax mixture, referred to above, seems to me to offer a much better sealing mixture that the commonly employed shellac preparations which may react upon the living cells.

V. CUTICULAR AND INTRACELLULAR TRANSPIRATION

	9 A. M.	10	11	12.30 P. M.	1.30	2 30	3.30	4.30	5.30
FICUS ELASTICA,	70	76	107	4	7	9	12	10	10
Temperature,	18.8		19.5				19		
Hygrometer,	50		52				48		
FICUS ELASTICA,		163	175	6	4	11	10	12	12
Temperature,		22						23	
Hygrometer,		48						45	
FICUS ELASTICA,	37	38	43	4	8	10	10	6	8
Temperature,	19.5			19			20		
Hygrometer,	47			46			43		

In the cases under consideration, where the diffusion owing to the nature of the leaf must be at a minimum, the results would appear to warrant the conclusion that the stomata are sufficiently open to permit diastomic transpiration during the night. The work of Blackman in demonstrating the slow diffusion of CO_2 through the cuticular membrane of leaves, likewise that of Morren in reference to the absorption of SO_2 are suggestive of a similar action for vapor gas. It would also be difficult to understand how respiration may in all cases be effected at night by diffusion. I have not been able to demonstrate that the stomata were open by

actual observation under the microscope but the rapid closing of the stoma in the case of plants standing in the shade suggests that possibly the balance between the tensions is so delicate that the least disturbance of the equilibrium, as in making the sections for examinations, may bring about the closing. It is also possible that, owing to the activity of the secreting cells and the accumulation of intracellular water, the stomata may open at varying periods and after the escape of the vapor close again. The rise in the rate after some one or more hours is perhaps due to the increase of water in the epidermal walls, induced by the turgor tensions. The work of Wiesner on the relative permeability of dry and moist membranes certainly points to such a conclusion. Comes has also demonstrated that the amount of water transpired from the two surfaces of the leaf when acting separately may be so increased that the total amount given off may exceed the normal transpiration of the leaf. The relatively large amount of water transpired in the third example after the sealing may be due to the quicker and stronger response in turgor tensions, thus bringing about a more rapid saturation of the epidermal membrane and there may also be an interaction on the stomatal apparatus.

Another feature of transpiration that emphasizes the intimate relation existing between the process and the vital action of the plant is the periodicity to be seen in the opening and closing of the stomata. Darwin has recently shown that the stomata have acquired the habit of opening more readily in the morning under the influence of light than in the afternoon. This is very strikingly shown in the experiments that are recorded in table VI.

The plants were given one hour illumination at various hours in the forenoon, indicated by the larger type, and for the same length of time in the afternoon. In the two last measurements the electric light was used. I have not a sufficient number of experiments at hand to warrant a conclusion as to the hour when the greatest response may be obtained and, owing to the very uncertain quality of the light from day to day as well as the influence of after effects, this would be a difficult if not impossible task. The results show in a very striking manner that there is a pronounced periodicity in the stomata of the plants under consideration. The stomata appear to open quicker and wider in the

VI. PERIODICITY OF THE STOMATA

IV.

	9 A. M.	10	11	12	1 P. M.	2	3	4	5	6	7
GERANIUM ZONALE,	56	60	*107*	78	67	49	44	*64*	46	40	
GERANIUM ZONALE,	60	68	*128*	78	80	62	45	*96*	55	36	
Temperature,	23					23.5			23		
Hygrometer,	47					47			49		
GERANIUM ZONALE,	19	23	24	*68*	46	28	24	*49*	28	25	23
Temperature,	25				24.5				24		
Hygrometer,	36				32				32		
GARDENIA FLORIDA,		48	*75*	65	62	32	40	*65*	40	27	30
JUSTICIA ELEGANS,		306	568	460	322	302	270	*302*	275	255	217
Temperature,		22.5						22		21.5	
Hygrometer,		48						51		53	
FUCHSIA SPECIOSA,	50	*103*	84	48	58	58	53	*71*	50	48	
Temperature,	20					21			20		
Hygrometer,	56					54			55		
AUCUBA JAPONICA,	43	43	*48*	44	46	43	42	*44*	40	40	
Temperature,	19.5							19.5			
Hygrometer,	59							58			
JUSTICIA ELEGANS,			196	175	180	*210*	176	167	150	*154*	136
Temperature,			20.5		20			19.5			
Hygrometer,			43		43			44			

morning. At least this might be inferred from the volume transpired and the reverse is true in the afternoon. Of interest also is the relation of the after effect. The volume for one or more hours following the period of illumination in the morning is in excess of the volume preceding the period of illumination. In the afternoon this relation may not hold good or there may be a slight excess in the volume following illumination over that of the preceding period. While the periodicity would assist in bringing about this relation it is evident that under the conditions of experimentation it could not produce so constant a rhythm.

One feature of this work that has been constantly before me is the extreme sensitiveness of the plant and the consequent necessity for the greatest care in avoiding the introduction of disturbing influences. Burgerstein's suggestion that transpiration phenomena, when possible, should be studied by weighing would appear to promise the most trustworthy results. When we consider the complex relations existing in the plant and their varied reaction to external conditions it would appear that much of the work that had been done upon this subject had been prosecuted

under exceptionally brutal conditions. Devices which employ shoots or portions of the plant are of great value for demonstrations rather than as a means for the exact determination of actual processes. This remark may also apply to the measurements obtained by condensation or absorption of vapor. Work conducted under so artificial and unusual conditions can only give uncertain results.

SUMMARY

On cloudy and stormy days when the intensity of the light is quite uniform or at least not in keeping with the time of day, the transpiration curve shows a pronounced maximum near midday and it is also characterized by minor fluctuations that occur independently of climatic changes.

An illumination of an electric light of 900 candle-power under uniform external conditions demonstrated a periodicity in the transpiration of several plants that corresponds in the main with the curves determined on cloudy days. The harmonizing of the rhythms of absorption, exudation and tension of fluids and the rate of growth is suggestive of the vital character of transpiration.

Variations of a few per cent. in the humidity of the atmosphere produced no change in the amount of transpiration that could be determined with certainty. An increase of 8 per cent. resulted in a marked drop in the rate.

The curve in the dark sometimes was in keeping with the rhythm found under constant illumination but more frequently it is characterized by variations quite out of keeping with the periodicity of light. There is evidently a cessation of the vital action of the plant and the retarding of the rate together with its more pronounced regularity is in keeping with the loss of tone manifest in the plant.

The very considerable volume transpired in the dark indicates that the stomata may be sufficiently open to allow the escape of vapor. This may be brought about in connection with the interchange of the gases in respiration or possibly by the independent action of certain stomata that are especially affected by the increased turgor tensions or vapor tensions of intercellular transpiration. Only in the case of *Cycas revoluta* did the amount of transpiration appear in keeping with the ratios determined for cuticular transpiration.

This supposition became more manifest when the stems and petioles of several plants of *Ficus elastica* were sealed and the rate of transpiration in the dark was measured for three hours after which the stomatal surfaces were sealed and the rate of cuticular transpiration was determined for four hours. This amounted to from 3.6 to 10 per cent. of the former volume.

The physiological character of transpiration is also indicated by the periodicity of the opening and closing of the stomata. They are more responsive to the stimulus of light in the morning than in the afternoon and the more considerable physiological activity in the morning is manifest in the more pronounced after-effect following the illumination in the forenoon.

Forcible Discharge of the Antherozoids in Asterella Californica*

By George J. Peirce

In January, 1901, I had a considerable number of male plants of *Asterella Californica* * on a plate under a bell-glass in the laboratory. The laboratory was moderately warm, the air fairly dry; the soil under the bell-glass was damp, the air moist. On removing the bell-glass to examine the plants more closely, I was presently surprised to see slight puffs of what looked like smoke coming from the sods. I scrutinized the material thinking there must be a puff-ball in it, but could see none. On the contrary, the little puffs of smoke came from different places over the plate and, on looking carefully, I thought they must come from the groups of antheridia. I held a glass slide over the plate, caught a puff or two on it, and examined it under the microscope. What I saw were great numbers of the antherozoids of this liverwort sticking to what had been the lower surface of the slide. I tried this again several times with the same result—the antherozoids were forcibly projected above the surface of the plant. The slides were held from five to ten centimeters above the plants, but I made no exact measurements at that time, for I was not sure that what I had seen was not a wholly unusual phenomenon, possible only under the unnatural conditions prevailing in the laboratory. The plants had been in the laboratory for some time—two weeks, possibly longer—on a table six feet from the window. They were average plants when I brought them in, but they had not developed in the laboratory so fast as plants which I had left undisturbed out of doors. It was impossible for me to test the plants out of doors for they were already too old to discharge any more antherozoids, so I was obliged to stop work on the matter for this reason.

From Professor D. H. Campbell, of this university, and Dr. M. A. Howe, of Columbia University, I learned that what I had seen was new, not hitherto recorded in the literature with which they are familiar and which is quite unknown to me, and I deter-

* This plant has also been known as *Fimbriaria Californica*.

mined to watch the plants out of doors as well as in the laboratory during the following season.

On January 20 of this year (1902) I thought the plants of *Asterella Californica* were in proper condition for testing whether they do or do not discharge their antherozoids under the conditions prevailing out of doors, and I set some glass slides to catch antherozoids if any should be expelled. A word may be said as to the weather and the place, as well as the manner and the result, of my experiment. The rains came early this season, in October and November, the season being ahead of the average when December began. There was no more rain to speak of till January 18. On December 11 the weather became decidedly cooler and remained cool, with frequent white frosts at night for weeks. There have been heavy dews and heavy fogs at night, some of the fogs being so heavy as to wet the streets enough to make the surface sticky. The days had been sunny as a rule, but there had been little growth and development among plants. In consequence, *Asterella* is not so far along as usual at this time. The bank where *Asterella* grows is sandy, steep, more or less covered with grass, shrubbery, mosses and liverworts, about half a mile from this university, and faces northeast, receiving little direct sunshine. On the morning of January 18 I was struck by the dryness of the soil there compared with last year. We had 20 mm. of rain the following afternoon and night; the sun shone brightly and the air was warm on the 19th. The plants were then in perfectly normal, healthy condition on the morning of the 20th, after a night of heavy dew and comparative mildness.

The sun was shining brightly, the air was rapidly growing warmer, as I set my slides at various distances from male plants of *Asterella*. The slides had been cleaned and numbered, and were held in place by wire holders thrust into the soil. The slides did not touch the plants and were in various positions, some horizontal, others oblique or vertical, corresponding to the positions of the plants. Slide no. 1 was 2–3 cm. from a patch of young *Asterella* growing on a vertical part of the bank. Other slides were nearer, others much further from the plants, from 0.5 cm. to 15 cm. I put out the first slides at 10.15 a. m., the last one at 11. At 4.30 p. m. I took a microscope out to the bank and looked

at some of the slides, but it was too late to examine all and the light was uncertain at best. Slide no. 1 had some dead antherozoids sticking to it. I did not see any on the other five slides examined. I put no. 1 back and brought the other five with me for more careful examination in the laboratory. The day had been warm and sunny, the air was much dryer during the day than at night, and there was some breeze throughout the day (a circumstance which might account for there being no antherozoids on any slides except no. 1). By seven o'clock in the evening it had begun to rain, and it rained gently for three hours.

There was white frost on the lowlands on the morning of January 21, but none on my bank. At 9.30 I took a microscope out again. Slide no. 1 had water on it, making a ridge along the lower edge on the side next the bank. I carefully took the slide out of the wire holder, turned it flat so that the water spread over the upper surface, and put it on the microscope. There were *Asterella* antherozoids in considerable numbers—a dozen in one field of Leitz objective VI and ocular 3—swimming about in the water. These antherozoids could have come upon the slide only as did those dead ones found on it the afternoon before, by being forcibly projected from the antheridia imbedded in the plants. It is evident, then, that the antherozoids are expelled when the plant is under perfectly natural conditions, and that what I saw a year ago was not a laboratory phenomenon merely.

From the conditions prevailing when I first saw the expulsion of these antherozoids, I thought the mechanics of the process might be as follows: that the walls of the antheridia and the adjacent tissues of the plant give up water in comparatively dry air faster than the contents of the antheridium can; that pressure develops which finally exceeds the resistance of the wall of the antheridium; that this breaks suddenly and the antherozoids are thus thrown out through the openings of the cavities in which the antheridia lie. This hypothesis seemed to be strengthened by my finding antherozoids in the afternoon, after a day of comparative dryness following a night when the dew was heavy. But the occurrence of antherozoids on the slide which was out all night and during a rain does not favor this view. The number of antherozoids on this was decidedly larger, perhaps because the

time of exposure was longer (about three times as long), perhaps because the antherozoids did not fall off the wet slide as they might from a dry one, perhaps because the breeze was gentler or different in direction, etc. The main thing is the occurrence of antherozoids on the slide under two sets of conditions very different from each other. The mechanics of expulsion cannot be such as I at first thought.

Having proved that *Asterella* expels its antherozoids out of doors under natural conditions and not merely in the laboratory, I decided to bring plants in for further study. So many things may act as disturbing influences out of doors—the wind, rain, animals, etc.—that no satisfactory tests of the distances to which the antherozoids may be thrown are likely to be made out of doors without a great expenditure of time and trouble. I brought a considerable number of male plants of somewhat different ages into the laboratory, arranged them on a plate, fastened to the edge of the plate wires holding slides at different heights above the plants, and covered the whole with a bell-glass, first taking care that the plants were thoroughly wet. On the afternoon of the following day I found a few antherozoids on one slide about seven centimeters above the plants. On the morning of the next day but one there were grayish spots on three slides, five to seven centimeters above the plants. These spots I feared were excrementitious matters from some insect but proved on examination to be extensive masses of antherozoids in the slime in which they are discharged. This slime consists presumably of the gelatinized walls of the mother-cells of the antherozoids together with whatever protoplasmic matters remain and degenerate in the mother-cells. The slime is very important in contributing to the expulsion of the antherozoids.

I put the slides on higher holders and waited another twenty-four hours, again watering the plants before putting the bell-glass over them. Much to my astonishment, on the following morning, one of the slides, fourteen centimeters above the plants, had a series of spots on it as shown in *Fig. 1*. This figure is a tracing, moderately exact as to the shape and size of the spots and exact as to their number and arrangement, made on thin paper from the stained preparation on the slide. These spots certainly

suggest fly-specks, but examination with the microscope proves them to be masses of antherozoids. I again put fresh slides on holders still higher, but I caught no antherozoids on these highest slides. Any one of these possibilities may account for this, namely: the plants may have stopped forming antheridia and have emptied all those already made, or none may have been ready to burst while the slides were up, or the slides may have been between instead of in the path of expelled antherozoids, or the slides may have been just too high to catch any. Certainly the antherozoids caught on the slide fourteen centimeters above the plants would have gone considerably higher if they had not been caught. The highest slides I put in place were about 21 cm. above the plants. One may say, then, that *Asterella* can throw its antherozoids, under favorable conditions, to a vertical height of 14–20 cm.

The spots made on the slide by the discharged antherozoids are dense or thin, close together or scattered, according as the slide receives the discharge from the antheridium before or after the discharge spreads out. The outlines of the spots represent cross-sections of the discharge at the height of the slide. In *Fig. 1* there are so many spots that two or three plants must have discharged their antherozoids upon the one slide. The outlines of the spots even under the microscope are very sharp, the antherozoids are held together in very compact masses, the slime serving as the matrix. On some slides, instead of such dense spots, there is an immensely larger number of smaller spots, visible only under the microscope. These spots consist (*Fig. 2*) of a considerable number of antherozoids in a thin layer of slime. The slime layer varies somewhat in thickness in different parts of the spot. From my slides it is obvious that the antherozoids are discharged while enclosed in slime, that the main mass of slime breaks up during its flight into smaller ones, these again dividing perhaps, and that finally the antherozoids fall again to the ground in little groups, the enclosing slime dissolving in the dew or rain, on the surface on which they fall, thus liberating the antherozoids. The antherozoids thereupon swim off, swimming then for the first time although they may have been carried far on the breeze which also helped to break up the discharge from the antheridium. The slime, holding the antherozoids together in little groups, is dis-

tinctly beneficial in so doing. It is a protection, besides, in keeping the antherozoids from drying and stiffening, as such minute bodies would surely do unless enclosed in a matrix which holds water more effectively than protoplasm. That there is always slime about the antherozoids till they fall on a wet surface is shown by my dry slides. That the slime dissolves, thus liberating the antherozoids, which thereupon swim away, is shown by my wet slide out of doors.

Antherozoids on the slide, whether singly or in patches, may be fixed and stained by the methods applied to staining cover-glass preparations of bacteria. I tried several methods, of which Fischer's * for staining cilia was the most successful. Of course, this method is not recommended for the cytological study of the antherozoids. I recommend it only for the purpose of demon-

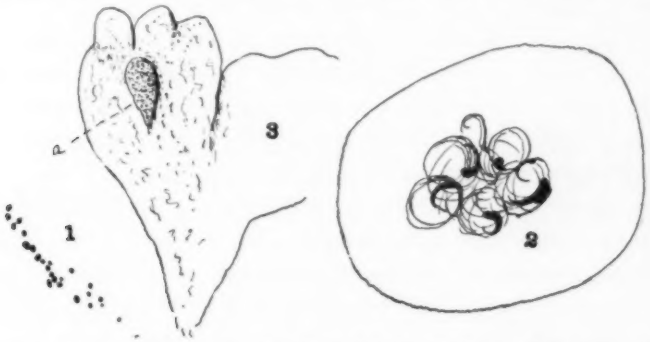

FIG. 1. A tracing of spots formed on slide by discharge of antherozoids from antheridia 14 cm. below.

FIG. 2. A very small spot, showing ciliated antherozoids and slime in which they are imbedded, × 755. Leitz drawing-prism.

FIG. 3. Sketch of male plant of *Asterella Californica*, showing cushion (*a*) in which antheridia develop, × 3.

strating perfect antherozoids, ciliated and enclosed in thin slime, which have been caught on slides.

We come back now to the mechanics of expulsion. The discharges which I have seen take place or have caught on the slides, have occurred only when the soil and the plants were full of water. Not only the tissues of the antheridia, but the surrounding vegetative tissues were turgid. Given an abundant supply of water in

* Jahrb. wiss. Bot. 27 : 82. 1895.

the soil, turgidity will always develop. The structure of these turgid parts demands a moment's notice. The antheridial patches of *Asterella*, as shown in *fig. 3*, are somewhat raised above the general surface of the thallus. The tissue composing and underlying this elevation is very different from that elsewhere. A section through one of these antheridial patches parallel with and below the surface of the thallus, shows that the thallus is composed in the main of moderate sized cells, containing many chlorophyll grains and with small intercellular spaces between, while the part of the thallus where the antheridia are consists of much larger cells, with far fewer chlorophyll grains, cell-walls no thicker, and (when the tissue is full of water) there are no intercellular spaces. The distribution of these tissues is plain to the naked eye, for the part under or among the antheridia appears quite colorless compared to the adjacent tissue rich in chlorophyll. *Fig. 4* shows such a section. The part of the section outside the bounding line consists of chlorophyll-containing rather small-celled tissue. Within the line one sees holes of various sizes and shapes between which are comparatively large, thin-walled cells pressed close together owing to their turgidity. (I sectioned a thallus from very wet soil.) In the spaces *a* and *b* were antheridia, in the other spaces there were none. Some of these spaces are nearly obliterated, as those lettered *c* and *d* show. *Fig. 5* is an enlarged drawing of the part *a* of *fig. 4*, that is, a cross section of an antheridium enclosed in the turgescent nearly colorless tissue of the cushion. The cells forming the wall of the antheridium are shown in outline (*a*), the adjacent and closely pressing vegetative cells are only partly shown (*b*), while the blank central portion (*c*) represents the mass of antherozoids enclosed in slime, forming the greater part of the antheridium. *Fig. 6* is a longitudinal section of an antheridium, a section at right angles to the surface of the thallus, similarly lettered. All the sections are free hand, and the one shown in *fig. 6* does not show in quite true proportions the opening of the chamber in which the antheridium lies. The tissue within the bracket *d* is composed of comparatively small cells, rich in chlorophyll, the tissue bracketed *e* is composed of large cells, comparatively poor in chlorophyll, and capable of great changes in volume. It is precisely this compara-

tively colorless tissue in which the antheridia are imbedded which furnishes much of the force by which the antherozoids are ejected.

The mechanism effecting the ejaculation of the antherozoids consists of two parts—*first*, of the shiny, water-absorbing matrix consisting of gelatinized mother-cells and thin walls, in which the antherozoids lie and which fills and distends the ripe antheridium still enclosed by the single layer of peripheral cells; *second*, the thin-walled, large-celled, water-absorbing tissue composing the cushion, in chambers of which the antheridia develop. These two, the tissue and the slime, expand in opposite directions as they absorb water, the one tending to decrease, the other to in-

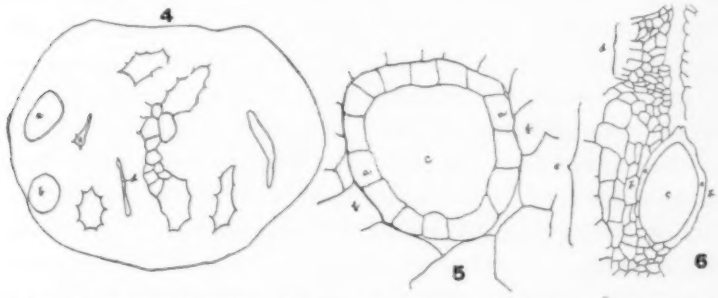

FIG. 4. Section through cushion, parallel to and below surface of thallus, showing cavities containing antheridia (*a* and *b*), empty cavities, and cavities nearly obliterated (*c* and *d*) by pressure of the thin-walled cells composing cushion, × 22.

FIG. 5. Enlarged drawing of *a* in *fig. 4*, × 172.

FIG. 6. Section through antheridium at right angles to surface of thallus, × 172.

The lettering in *figs. 5 and 6* denotes: *a*, wall of antheridium; *b*, turgid cushion-tissue compressing antheridium; *c*, mass of antherozoids in slime composed of degenerated walls and contents of mother-cells. This absorbs water and distends antheridium; *d*, solid chlorophyll-containing tissue, with opening of chamber; *e*, water-absorbing turgescent cushion-tissue. The figures were drawn with Leitz drawing-prism.

crease, the size of the chambers containing antheridia. The two pressures would tend to offset each other and would affect nothing if they met on all sides of the antheridia. The chambers in which these lie, however, are open above and are covered by the chlorophyll-containing, smaller-celled, and more rigid tissue indicated by *d* in *fig. 6*. Hence the antheridia are distended in all directions, upward as well as otherwise, and are compressed from all sides, *except from above*. The distending and compressing strains finally result, under these considerations, in the rupture

of the antheridium and the discharge of its contents through the mouth of the chamber, the total force expanding itself all in one direction with the astonishing result just described.

The distance to which antherozoids will be thrown will depend on the one hand upon the turgidity of the antheridia and of the vegetative parts of the plant, and on the other hand upon the position of the plant and upon the wind. The antherozoids may be thrown violently against nearby objects, leaves, branches, etc., when the force was sufficient to have carried them much farther if the plants had only been growing in more open places. But the main external influences are wind and water. The wind may blow the antherozoids back upon the parent plant or take them far away, dropping them near female plants or scattering them where there are none. When the antherozoids fall to the ground they must swim the rest of the way if they are to accomplish their purpose. An enormous number of antherozoids are discharged from each antheridium, and there are several or many antheridia on each male plant. Without counting at all, I should say that there appear to be about equal numbers of male and female plants, and that the number of archegonia is about the same as the number of antheridia. At all events the number of antherozoids enormously exceeds the number of egg-cells. Since these plants are dioecious, cross fertilization is all that is possible. But what does the plant pay for this? The dioecism of this species is coupled with the forcible discharge of the male elements. These may or may not be transported by this means nearer to the female elements which they must reach by swimming and with which they must fuse if they are to be useful.

It would be interesting to know whether other dioecious liverworts have this same habit. I hope next year to test other plants for this phenomenon, but I do not wish by this statement to reserve the field to myself.

PHYSIOLOGICAL LABORATORY,
LELAND STANFORD JUNIOR UNIVERSITY,
January 31, 1902.

Taxodium distichum and related Species, with Notes on some geological Factors influencing their Distribution

By Roland M. Harper

Observations on the genus *Taxodium* in the field during three or four seasons have led me to the conclusion that there are at least two well-marked species in the southeastern United States. Most authors who have written on the subject have considered the genus to be represented in that region by a single species, but some have admitted the existence of a variety in addition.

The genus was founded by L. C. Richard in 1810, with a single species, the *Cupressus disticha* of Linnaeus; and the number of living species in the world has since been variously regarded as from one to three, excluding species which are now referred to *Sequoia* and *Glyptostrobus*.

Before discussing the relationships of the two southeastern species it will be well to give their principal synonymy, which is as follows:

Taxodium distichum (L.) L. C. Richard, Ann. Mus. Par. **16**: 298. 1810

Cupressus disticha L. Sp. Pl. 1003. 1753. Type locality: "Virginia, Carolina."

Schubertia disticha Mirbel, Mem. Mus. Par. **13**: 75. 1825.

Taxodium imbricarium (Nutt.)

Cupressus disticha β *imbricaria* Nutt. Gen. **2**: 224. 1818.

Type locality: "From Florida to North Carolina, in swamps and ponds more remote from the sea."

Taxodium ascendens Brong. Ann. Sci. Nat. **30**: 182. 1833.

Type locality North American, but not specifically given.

T. distichum var. *imbricarium* Sarg. Sylva N. A. **10**: 152. 1896.

The latter form of the name was used by H. B. Croom in his Plants of New Bern (now Newbern), N. C., in 1837, by M. A. Curtis in his flora of North Carolina in 1867, and by Wood & McCarthy in their Wilmington (N. C.) Flora in 1886, but does

not seem to have been properly published until it was taken up by Professor Sargent. Synonyms for these two species which are purely horticultural or of doubtful application are here omitted.

The principal objection to the recognition of the latter species as distinct seems to have been its supposed intergradation with *T. distichum*. Elliott,* writing a few years after Nuttall, says of *T. imbricarium:* "This is a small tree growing in pine-barren ponds. It produces its knobs (exostoses) more abundantly than the large variety; and on its lower branches the leaves are frequently imbricated after the manner of the junipers. But on the upper branches the leaves are often expanded and distichous. It is perhaps only a stunted variety, growing in an unfavorable soil."

Seventy-two years later Professor Sargent† remarks: "No one unfamiliar with the fact that branches of the two forms occasionally appear on the same individual would imagine that the cypress trees with erect or pendulous thread-like branches and closely appressed acerose leaves belong to the same species as those with spreading distichous branches and flat leaves."

Dr. Mohr's observations on *Taxodium* in his "Plant Life of Alabama"‡ are of interest as being among the latest published. On page 117, in speaking of the mesophile and paludial forests of the lower division of the coast pine belt, he says: "Groves of the pond or upland cypress just mentioned—a variety closely connected with the type by intermediate forms—cover the shallow pine-barren ponds and semi swampy woods of a poor, sandy soil destitute of vegetable mold. This form of the cypress in the size and quality of its wood is greatly inferior to the typical cypress of the alluvial swamps, and is at once recognized by the leaves, which are closely appressed to the deciduous annual shoots. By this peculiarity of the foliage a check to excessive transpiration is provided during the time of drought, when the sandy soil is laid bare to the sun and its supply of water is failing."

On page 325 he says of the same plant: "Of smaller size than the species, with the leaves reduced in size and closely adpressed to the deciduous branchlets, thus imparting to the tree a strikingly

* Bot. S. C. & Ga. **2**: 643. 1824.
† Sylva N. A. **10**: 152. 1896.
‡ Contr. U. S. Nat. Herb. **6**: 1901.

peculiar aspect. This character, however, is not constant, and the variety can scarcely be maintained, the same individual producing during the earliest stages of growth and on vigorous adventitious shoots leaves of the ordinary form. This form passes freely into the species where the soil conditions are more favorable."

But, notwithstanding the opinions of these eminent botanists, it seems to me that the intergradation is more apparent than real, and that this idea may have arisen from a too hasty generalization of observed facts. It is true that young shoots of *T. imbricarium* often bear branchlets with distichous leaves (perhaps indicating its descent from an ancestral form which resembled *T. distichum* of the present day), but on the typical *T. distichum* I have seen only one kind of branchlets.

The opinions of Nuttall and Croom, both of whom seem to have been very acute observers, are more favorable to my view of the distinctness of the two species under consideration.

Nuttall, in the original description of *T. imbricarium*, says: "Leaves subulate, partly imbricated in four ranks, deciduous; nuts larger, chestnut colored." * * * "A smaller tree than the preceding, often producing fruit at a height of three feet from the ground."

Croom, in his flora of Newbern above mentioned, says (page 48): "*Taxodium distichum.* * * * Elliott expresses the opinion that the variety *imbricarium* of Nuttall is only this species in a starved condition, as it is commonly found in pine-barren ponds. But in some instances (20 miles above New Bern) I have seen large trees of this variety, and, in one instance, I observed it growing by the side of the common variety, and in the same soil."

The differences between the two species will now be considered more in detail. These differences are of several kinds, not only structural but ecological as well.

The most conspicuous structural difference, as noted by most of the authors just quoted, is in the form and position of the leaves and the branchlets which bear them. In *T. distichum*, as is well known, the leaves are two-ranked on the branchlets, widely spreading, and in the same plane, making each leafy branchlet resemble a pinnate leaf (to which it is indeed analogous); and the branchlets spread approximately horizontally, bringing the surfaces

of the leaves likewise into a horizontal position. In *T. imbricarium*, on the other hand, the leaves are normally more or less appressed to the branchlets, which have lost their dorsiventral character. The branchlets have been described by Professor Sargent and others as "erect or pendulous," and from a herbarium specimen it would usually be impossible to ascertain which of these two positions they had assumed in life. But they would be much more correctly described as normally erect, occasionally somewhat spreading, very rarely (never in perfect specimens) drooping. It is interesting to note that the leaves and branchlets of the two species of the allied genus *Sequoia* differ in much the same way.

I have not noticed any difference between the fruits of the two species, but Nuttall says of *T. imbricarium* "nuts larger," and Endlicher * probably following Nuttall, says of *T. ascendens* Brong., "seminibusque majoribus."

The difference in size, mentioned by some authors, does not appear to be constant, as remarked by Croom. In Georgia, where both species are abundant, *T. imbricarium* often attains as large a size as *T. distichum*, but the former probably begins to fruit at a smaller size (though perhaps not at an earlier age, as it is said to be of slower growth).

One characteristic difference, which does not seem to have been noted before, is found in the enlargement at the base of the trunk, which is usually more abrupt in *T. imbricarium* than in *T. distichum*. In Coffee county, Georgia, I have walked entirely around a specimen of *T. imbricarium* on its enlarged base, a feat which would be impossible with any specimen of *T. distichum* I have ever seen. Furthermore, the enlargement of the trunk of *T. distichum* is approximately conical, with its greatest slope at or below the surface of the ground (or water, as the case may be), while that of *T. imbricarium* is conoidal, with its greatest slope some distance (a few inches to a foot or two) above the ground. In the many thousands of individuals of *T. imbricarium* which I have seen I have never observed any deviation from this character. The longitudinal ridges traversing this enlargement are usually quite sharp and prominent in *T. distichum*, and rounded

* Syn. Con. 69. 1847.

or almost wanting in *T. imbricarium*. The same differences are often observable in cultivated specimens.

The general appearance of the trunk of *T. distichum* is well shown in figure 48 of Schimper's Pflanzengeographie, which is a full page half-tone reproduction of a photograph taken by Dr. H. J. Webber in Florida,* also by plate 8 and figure 30 of Professor N. S. Shaler's paper on the fresh-water morasses of the United States in the Tenth Annual Report of the U. S. Geological Survey, and by plate 73 in Mr. Kearney's recent paper on Dismal Swamp,† which is the same as Professor Shaler's plate 8.

Plate 68 of Mr. Kearney's paper illustrates very well the character which I have just assigned to *T. imbricarum*, and plate 9 of Professor Shaler's paper, which was evidently photographed at about the same time and place, shows the same thing, though less distinctly. By comparing these plates with the illustrations of *T. distichum* just cited, the difference is readily seen. Nothwithstanding the fact that this species is not mentioned by Mr. Kearney in his paper (and he has since told me that he is not acquainted with it), I am confident that his plate 68 and Professor Shaler's plate 9 represent the true *Taxodium imbricarium*. I find no other record of the occurrence of *T. imbricarium* in Virginia than these two illustrations, but Croom found it near Newbern, N. C., which is only about 100 miles from Lake Drummond, Virginia, where the photographs in question were taken.

Whether the knees afford any diagnostic characters or not I am unable to state at present. Elliott mentions those of *T. imbricarium* as being more abundant than those of *T. distichum*, but this may not be universally true. Professor Shaler (in the paper above cited) and perhaps other authors, have noted that *T. distichum* cannot live with its knees under water during the summer. This is probably not true of *T. imbricarium*, for I have seen it in midsummer in ponds and creeks where no knees were visible, at least at the ordinary stage of water. The knees of *T. imbricarium* probably never become so large as those of *T. distichum*.

Physical tests show an appreciable difference in the wood of the two species. Dr. Filibert Roth, in one of the publications of

* The same photograph is reproduced in Coulter's "Plant Relations," as Fig. 91.

† Contr. U. S. Nat. Herb. 5: 321–550. *pl. 65–77. f. 51–90.* 6 N. 1901.

the U. S. Department of Agriculture,* although not regarding the two forms as specifically or even varietally distinct, has tabulated the results of many tests which show that the wood of the "pond-cypress" is both heavier and stronger than that of the better-known plant.

Turning now to ecological characters, the leaf-galls may be considered next. The leaves of both species are frequently more or less infested with galls, and as far as I have observed the galls on the two species appear to be different. Whether they are caused by the same or different insects I do not know; this is a matter which deserves further investigation.

In regard to habitat, it seems to be the prevailing opinion that *T. distichum* is confined to river swamps and *T. imbricarium* to pine-barren ponds. This, however, is not always the case. The largest specimens of *T. imbricarium* I have ever seen are in southeastern Georgia, in deep-flowing water of creeks which never dry up, and yet they maintain their essential characters perfectly. Here the species is to all outward appearances growing under practically the same conditions which prevail in the rivers and creeks which *T. distichum* inhabits. The habitat of the latter is also somewhat variable, including lime-sinks as well as river-swamps. Some say that *T. imbricarium* grows in poorer soil, but this also is liable to many exceptions, to say nothing of the difficulty of defining accurately what constitutes a poor soil.

In view of all these well-marked and constant differences, and others to be mentioned later, it seems to me that *Taxodium distichum* and *Taxodium imbricarium* can no longer be consistently treated otherwise than as distinct species. They are certainly as distinct as *Lycopodium lucidulum* and *L. porophilum*, *Juniperus Virginiana* and *J. Barbadensis*, *Pinus palustris* and *P. heterophylla*, and a hundred others which might be mentioned.

During my investigations of the flora of Georgia in 1900, I discovered a most remarkable relation between the habitats of these two species of *Taxodium* and the geological formations, on which I have based a new theory of their distribution. This theory has so far been fully substantiated by observed facts in almost every case, and the few apparent exceptions to it which have been

*Circ. Div. Forestry, 19: 22. 1898.

noted will probably disappear on closer investigation. It may be briefly stated as follows:

Taxodium imbricarium always grows over the Lafayette formation; Taxodium distichum never.

Furthermore, *T. imbricarium* seems to occur only on Lafayette which is overlaid by a thin deposit of the Columbia formation, and *T. distichum* is often, if not usually, found on the Columbia also, but where this formation is absent it may grow directly on the older strata.

The Lafayette and Columbia formations have been thoroughly discussed by W J McGee,* but a brief outline of them here may be of interest to those who have not time to read the one hundred and seventy-five quarto pages of his monograph.

The Lafayette, the older of the two, is (at least throughout most of the region in which *Taxodium imbricarium* occurs) a deposit of sandy clay, reddish or yellowish in color, varying considerably in thickness, lying unconformably on the mesozoic and cenozoic strata over a vast area of the coastal plain of the eastern United States. It is supposed to have been laid down just before the Glacial period of the North, during a submergence of the coastal plain estimated to have lasted about 60,000 years.

The Columbia formation, in the region under consideration, consists almost entirely of sand. It is supposed to have been deposited during a much shorter period of submergence of the coastal plain contemporaneous with or subsequent to the glacial period. It is always above the Lafayette where the two come in contact, and is rarely too thick for the roots of trees to penetrate through it into whatever strata may be beneath.

In a general way the terrane of the Lafayette may be said to coincide with the present coastal plain from Maryland to Texas, extending up the Mississippi Valley to Illinois, with the following exceptions. It is not known to cover any portion of Florida except the extreme north, the peninsula having perhaps been too far off shore during the Lafayette submergence to receive any of these sediments. Neither is this formation known to extend to the present shore line at any point.

During a period of elevation succeeding the Lafayette submer-

* Ann. Rep. U. S. Geol. Surv. 12[1]: 347–521. *pl. 32–41. f. 28–72.* 1891.

gence the larger rivers of the coastal plain cut their channels entirely through the Lafayette deposits into the older strata below, and in most of the resulting gorges the Columbia sands were subsequently deposited.

Like the Lafayette, the Columbia covers a large part of the coastal plain, extending from Long Island to Mexico, and up the Mississippi and Ohio rivers to Indiana. In the Middle and South Atlantic States it covers the whole country near the coast, but usually does not extend up to the inland edge of the coastal plain like the Lafayette. In southwestern Georgia and Alabama, however, it is mostly confined to the river valleys, the divides here having been above the sea during the Columbia submergence. In Texas, while the main body of the Columbia only covers the seaward portion of the coastal plain, long narrow arms of this formation extend several hundred miles up the larger rivers, far beyond the inland edge of the costal plain. Similar extensions are found in Arkansas and the Indian Territory. On the peninsula of Florida the Columbia formation has not been traced south of latitude 28°.

The geographical distribution of our two species of *Taxodium* is intimately related to that of the two geological formations just mentioned, as will now be shown.

The range of *T. distichum* is given by Professor Sargent * as follows: "From southern Delaware * * * southward near the coast to the shores of Mosquito Inlet and Cape Romano, Florida, through the coast region of Gulf States to the valley of the Devil River in Texas, and through Louisiana and Arkansas to southeastern Missouri, eastern Mississippi and Tennessee, western and northwestern Kentucky, southern Illinois, and Knox county in southwestern Indiana."

The range thus given of course includes that of *T. imbricarium* also, but according to my theory *T. distichum* would be confined to the comparatively small but widely distributed area from which the Lafayette formation is absent, such as near the coast, along the larger rivers, and on the peninsula of Florida.

Among the extreme points of the range of *T. distichum* may be mentioned the following:

* Sylva N. A. 10: 153. 1896.

Dr. Hollick* has reported its occurrence near Newark, N. J., but is not certain that it is indigenous there. This locality is near the extreme northern limit of the Columbia formation, and about 200 miles from any known area of the Lafayette. The occurrence of *T. distichum* at this point therefore does not conflict with my theory. The Lafayette formation is also unknown in Delaware, which is the northernmost state in which *T. distichum* is undoubtedly indigenous at the present time.

Dr. Gattinger, in his Flora of Tennessee (pages 25 and 32 of the 1901 edition), mentions its occurrence along the Tennessee River, which, according to Dr. McGee's map of the Lafayette and Columbia formations (plate 38 of his monograph above cited), has cut through the Lafayette and is now lined by deposits of Columbia throughout most of its course through the western part of the state.

Dr. Mohr† says of the range of *Taxodium distichum* in Alabama: "This tree is found throughout the State," but this statement is probably to be taken with some qualification. Among the particular localities mentioned by him is the Tennessee River; and although the Columbia formation is not known to extend up this river into Alabama, the *Taxodium* might well do so, as it is not necessarily confined to this formation.

The occurrence of *T. distichum* in Knox county, Indiana, has been discussed by John S. Wright.‡ In Garden and Forest (**3**: 7. *f.* 2) for January 1, 1890, there is a good half-tone engraving of an Indiana cypress swamp.

An interesting station for *T. distichum* in Texas was discovered in 1894 by Mr. A. A. Heller, who collected it along the Guadalupe River at Kerrville, at 1600 feet altitude.§ One of his specimens from this locality is in the Columbia University herbarium. Kerrville is beyond the known area of the Columbia formation, but it is noteworthy in this connection that this formation extends farther inland and higher above sea level along the rivers of Texas than anywhere else. According to Mr. Heller's report, Kerrville

* Ann. Rep. State Geol. N. J. 1899: 181. 1900.
† Contr. U. S. Nat. Herb. **6**: 46. 1901.
‡ Proc. Ind. Acad. Sci. 1897: 172–175. 1898.
§ *Cf.* Contr. Herb. F. & M. Coll. 1: 9. 1895.

is "situated in a limestone formation." On investigation I find that this formation is lower Cretaceous. Professor W. L. Bray, of the University of Texas, to whom I wrote for further information about the range of *T. distichum* in that state, informs me that it occurs on almost every stream in the Cretaceous area of Texas and probably on all on the Rio Grande Plain, also in all the bayou country of east Texas, north to the Indian Territory line. Dr. Havard, in his "Report on the Flora of Western and Southern Texas," * mentions several stations for this species in the extreme southern part of the state.

The southeastern limit of *T. distichum* has been placed by Professor Sargent at Mosquito Inlet (about lat. 29°) on the east coast and at Cape Romano (about lat. 26°) on the west coast of Florida, but Dr. Small, who has recently been in southern Florida, tells me that it extends down the east coast to Miami (which is farther south than either locality mentioned by Professor Sargent) and is common in the Everglades near by. This is considerably beyond the known area of the Columbia formation, but still farther from the Lafayette.

In Georgia, to which state my field work on this genus has been confined, I have seen *T. distichum* on the Oconee River in Montgomery county, on the Ocmulgee in Dodge and Wilcox, on the Flint in Sumter, Dooly, Dougherty and Decatur, on the Ochlocknee in Thomas, on the Chattahoochee River and Sowhatchee Creek in Early, on Lime Creek in Sumter and Gum Creek in Dooly, on Muckalee Creek in Lee and Kinchafoonee in Lee and Terrell, on Spring Creek in Decatur, Ichawaynochaway in Calhoun and Chickasawhatchee in Dougherty; from all of which points the Lafayette formation is known or believed to be absent. I have also observed this species in a few scattered localities away from the rivers in Sumter, Lee and Dougherty counties (from which localities the Lafayette may be inferred to be absent, though we have as yet no direct evidence that such is the case), and in lime-sinks near the Flint River in Dooly county. Other botanists have collected or observed it along the Savannah and Altamaha rivers; and it doubtless extends from all the points just mentioned down each river nearly or quite to its mouth.

* Proc. U. S. Nat. Mus. 8: 504. 28 S. 1885.

The range of *T. imbricarium* is not so well known, as comparatively little attention has been paid to this species. Although it appears to be much more abundant than *T. distichum* in most of the states in which it grows, most botanists who have observed it have probably considered it identical with that species, and therefore made no especial note of it. It is not even mentioned in any edition of Chapman's "Flora of the Southern United States."

Professor Sargent * says of the range of this species: "The acerose form * * * is not uncommon in South Carolina, in northern Florida, and in the neighborhood of Mobile, Alabama." It has also been reported from North Carolina by Nuttall, Croom and others, and is very abundant in Georgia, where it perhaps reaches its best development. The evidence in favor of its occurrence in Virginia has already been given. Outside of these six states I find no record of it.

T. imbricarium is common wherever the conditions of soil and topography are favorable for its development, in those portions of the coastal plain where both the Lafayette and Columbia formations are present, away from the coast and larger rivers. It seems to approach nearest to the coast in North Carolina, where Wood and McCarthy have recorded a station for it in their Wilmington Flora,† in a swamp about six miles from the ocean, in New Hanover county. In Chatham county, Georgia, I noticed last June that it extended to within twelve miles of Savannah on both the Central of Georgia and Georgia and Alabama Railways. These two railroads run almost perfectly straight through the county, and at the points mentioned they are about a mile apart. On consulting Mr. McGee's map I found that these localities are just at the coastward edge of the Lafayette formation, thus furnishing additional evidence in support of my theory.

Of the inland limit of *T. imbricarium* little is known. In the eastern part of Georgia I have seen a few specimens as far up as Millen, 78 miles from Savannah, and in the western part it is abundant in certain spots as far up as the southeastern corner of Sumter county, 200 feet above sea-level, 180 miles west of Savannah and about 125 miles north of the Gulf of Mexico. Here it

* Sylva N. A. 10: 152, in footnote.

† Jour. Elisha Mitchell Sci. Soc. 3: 123. 1886.

extends to the inland edge of the Oligocene strata. Croom * has reported it from Hartford, Ga. (a settlement, now extinct, which was near the Ocmulgee River in Pulaski county, about opposite the site of the modern town of Hawkinsville), which is about the same distance from the Atlantic coast as that last mentioned.

Between these limits *T. imbricarium* is very abundant in Georgia; and I will here give its observed distribution in the state somewhat in detail, as it is on these observations that my theory of its distribution is chiefly based.

East of the Ogeechee River it is abundant in the wet pine-barrens of Chatham and Effingham counties, and is sparingly represented around Millen, in the southern corner of Burke. West of the Ogeechee, in Emanuel and the upper part of Bulloch, I have seen it only in creeks and small rivers, where, as before mentioned, it attains a considerable size. Traveling westward along the Georgia and Alabama Ry., I saw it last July at many points in the pine barrens of Tattnall, Telfair, Dodge, Wilcox and Dooly counties, extending to within eight or ten miles of Cordele. Between Cordele and the Flint River the Columbia formation seems to be absent, and *Taxodium imbricarium* likewise. Farther south it occurs in wet pine-barrens or in small sluggish pine-barren streams in Worth, Berrien, Coffee, Ware and Appling counties. In the upper part of Coffee county, as for instance in the vicinity of Douglas, it grows also in creeks as in Bulloch.

In Sumter it seems to be confined to a number of shallow ponds about three miles from the Flint River in the southeastern corner of the county, where the Lafayette and Columbia formations overlap a short distance. Southward from there, it is very abundant in Lee county, and occurs in Dougherty, Calhoun, Mitchell, Miller, Early, and the northern parts of Thomas and Decatur, in the terrane of the Lower Oligocene. Throughout this part of the state its usual habitat is in shallow pine-barren ponds which sometimes dry up in summer, which it occupies to the exclusion of other trees. But in Thomas and Decatur counties (east of the Flint River) I have seen it in permanent ponds several hundred acres in extent and probably five or six feet deep, con-

* Am. Jour. Sci. **28**: 166. 1835.

taining a luxuriant growth of various Nymphaeaceae and other strictly aquatic plants.

At every point where *Taxodium imbricarium* has been observed all the indications are that both the Lafayette and Columbia formations are present, though of course I have been able to actually verify this only in comparatively few cases.

The cause of the preference of these two species of *Taxodium* for different superficial formations is as yet unknown, but the comparative imperviousness of the Lafayette clays doubtless has something to do with it.

If my theory is absolutely correct, these two species would never be found together. One or two exceptions to this have been noted. On July 13, 1901, I found both species together in a swamp in the pine-barrens in the northeastern part of Lee county, Georgia. But it is noteworthy that the specimens of *T. distichum* appeared stunted and unhealthy, while those of *T. imbricarium* were of the usual size and appearance. One explanation of their occurrence together might be that the seeds of *T. distichum* had been brought there in some manner and that the trees had managed to grow in spite of the unfavorable environment. I did not notice any fruit on these specimens of *T. distichum*, and the species is perhaps not reproducing itself at this locality. A similar or analogous state of affairs may prevail at the locality in North Carolina mentioned above, where Mr. Croom observed both species growing together.

It might be remarked here that there has been some difference of opinion among geologists as to whether the Lafayette formation extends beneath the Okefinokee Swamp in southeastern Georgia. If my theory is true this question could easily be settled by a determination of the species of *Taxodium* inhabiting the swamp. So far as I know no botanist has yet penetrated this vast swamp, but there can be no doubt that it contains at least one of the species of *Taxodium*, for cypress timber is said to be one of its principal resources, and the chief cause of the destruction of the swamp which is unfortunately now in progress.

In addition to the influence of the Lafayette and Columbia formations on the distribution of these two species, the older underlying strata also seem to have a considerable influence. For in-

stance, both species seem to grow only over calcareous substrata. *T. distichum* is almost entirely restricted to the Cretaceous and later formations of the coastal plain, but if Dr. Mohr's report of its occurrence on the Tennessee River in Alabama is correct, it there extends beyond the inner edge of the coastal plain into the Palaeozoic region. In Georgia it does not seem to extend even as far inland as the Cretaceous, but probably neither the topography nor the chemical composition of the rocks in the Cretaceous region of Georgia are adapted to either species of *Taxodium*, for the country is quite hilly, with few swamps or ponds, and the rocks are mostly argillaceous.

The habitat of *T. imbricarium*, so far as underlying formations are concerned, seems to be still more restricted than that of *T. distichum*. I do not know of its occurrence on strata older than Tertiary, and it may not extend farther inland than the Oligocene division of the Tertiary.

The difference between *T. distichum* and *T. imbricarium* may be of comparatively ancient origin, for fossils resembling both species are found in the Cretaceous and Tertiary strata of North America and Europe. Some of the fossil species of *Taxodium* with spreading leaves are referred to our living species *T. distichum*, but those with appressed leaves are usually referred to the related genus *Glyptostrobus*, which seems to be represented among living plants only by a single Asiatic species. More will be said of this genus later.

But if both of our species of *Taxodium* have existed since Cretaceous times, the question will naturally arise, what were their respective habitats before the Lafayette period, and also during that period, when the present coastal plain was all submerged? I am not prepared to answer this question completely, but would suggest as a partial solution that *T. imbricarium* has been evolved from the ancestors of *T. distichum* since the Lafayette period, and for this reason the two species are not yet as completely differentiated as are those of more ancient origin. The occurrence of distichous spreading leaves on the branchlets of the young shoots of *T. imbricarium* would seem to substantiate this view, for young shoots are usually supposed to show ancestral characters.

It seems to be a well-established fact that *T. distichum* grew

as far north as Greenland in Miocene times. With the advance of the ice-sheet during the Glacial period it was probably driven southward into Mexico, where the same species or a closely related one exists to-day. In the meanwhile the deposition of the Lafayette formation had taken place, and with the retreat of the ice our *Taxodium* doubtless migrated northward and eastward until it occupied its present territory. It was probably during this migration over the newly deposited Lafayette that the differentiation into two species took place, and *T. imbricarium* was evolved.

Some of the authors quoted at the beginning of this paper have mentioned the occurrence of forms intermediate between *T. distichum* and *T. imbricarium*. These might be of two kinds: first, individuals bearing branchlets of both kinds, and second, individuals all of whose leaves are intermediate in form and position.

The first case has been already discussed, and seems to present no difficulty. Individuals of the second kind also exist, and may perhaps even represent a distinct species. Such an intermediate form is probably what Brongniart * described as *Taxodium microphyllum*, and Parlatore † as *T. distichum β microphyllum*, so that names are not lacking for it. The only locality cited by Parlatore for his variety is Louisiana, while the typical *T. imbricarium* is not known west of Alabama. This may be an indication of the progressive differentiation of the species as the genus migrated eastward along the Gulf coast after the Glacial period.

In Georgia I have seen this intermediate form only in and near the Ogeechee River, at Millen, Ogeechee, Rocky Ford and Meldrim. What the relations of the Lafayette and Columbia formations are at these points I have not yet determined.

There is another supposed species of *Taxodium* in Mexico, *T. mucronatum* Tenore, of which comparatively little is known. Most of the accessible information about it has been summed up by Professor Sargent,‡ who is inclined to believe that "it may prove to be a mere geographical form of our tree." Professor Bray, in writing to me of the range of *T. distichum* in Texas, expresses the opinion that this species as it passes into Mexico

* Ann. Sci. Nat. 36: 182. 1833.

† DC. Prodr. 16: 441. 1868.

‡ Sylva N. A. 10: 150. 1896. Gard. & For. 10: 451. July 17, 1897.

becomes "Sonorized," as several other species do, and is another thing. It is possible that *T. distichum* intergrades with *T. mucronatum* as suggested by Professor Bray. The two species are scarcely distinguishable in the herbarium, the characters by which they are separated being mostly phaenological. Mr. Heller's specimens from Kerrville, Texas, seem to resemble the latter as much as they do the former, at least in their visible structural characters.

One other point now remains to be considered, namely, the relation between *Taxodium* and *Glyptostrobus*. The latter genus was founded by Endlicher (Syn. Con. 69) in 1847, with two species, *G. heterophyllus* and *G. pendulus*, said to be natives of China. (He enumerates also in the same work three species of *Taxodium*.) In 1880 this genus was united with *Taxodium* by Bentham and Hooker (Gen. Pl. **3**: 429). Eichler, in his treatment of the Coniferae in Engler and Prantl's Natürlichen Pflanzenfamilien, keeps the two genera apart, but considers the reasons for so doing scarcely sufficient. This subject has recently been more fully discussed by Dr. M. T. Masters,* who gives very good reasons for considering the two genera distinct. I have seen only one specimen of *Glyptostrobus* (*G. heterophyllus*, in the Columbia University herbarium) myself, but its appearance suggests that its leafy branchlets might not fall off with the leaves as in the case of *Taxodium*. This point is not mentioned by the authors just cited, and I have no means of verifying it at present.

But the question of the identity of *Taxodium* and *Glyptostrobus* is not of such immediate interest to us as the relation of *Taxodium imbricarium* to *Glyptostrobus pendulus*. These were both mentioned by Endlicher in his Synopsis Coniferarum who seems to have had no suspicion of their similarity, but they have been regarded as identical by some authors, and this is probably the case. Professor Sargent treats them as identical in his Sylva of North America (**10**: 152. 1896), and in Garden and Forest (**10**: 451) for July 17, 1897, writes as follows: "The tree which in the United States and Europe is almost universally called *Glyptostrobus pendulus*, is really a juvenile [*sic*] form of the *Taxodium* of the Southern States, *Glyptostrobus* being a south China genus

* Jour. of Bot. **38**: 37–40. Feb. 1900.

with a single species, which has possibly never been brought to the United States, and which would not be hardy in this part of the country" [Massachusetts]. "It is a comparatively small tree in its native swamps, and, in spite of its southern home, is hardy in New England, where it is one of the most distinct and beautiful of the pyramidal conifers. The proper name for this tree is *Taxodium distichum*, var. *imbricarium*."

In front of the main building of the Department of Agriculture in Washington there are two trees of this species one labeled "Chinese Water Pine, *Glyptostrobus pendulus*, China," and the other the same except that it is called *G. Sinensis*. Scattered about the parks of the city are many similar specimens, as well as some of *Taxodium distichum*. Although they are rather pyramidal in shape, unlike *Taxodium imbricarium* in its native habitat, they have the appressed leaves and erect branchlets of that species, and seem to differ only in their peculiar shape, which is probably only the result of long cultivation under unnatural conditions. The only specimen of "*Glyptostrobus pendulus*" in the Columbia University Herbarium is from a tree cultivated in Philadelphia, and on the back of the sheet is written a note to the effect that it came from a seedling of *Taxodium distichum*.

In the Gardener's Chronicle (III. **26**: 489. *f. 161*) for December 30, 1899, there is a figure of one of these cultivated specimens growing in England, and it is there contrasted with *Glyptostrobus heterophyllus*, its identity with *G. pendulus* evidently being taken for granted.

The question might now arise: Are there really two species of *Glyptostrobus* in Asia? Apparently not; for no flora of China or Japan to which I have had access contains any reference to *G. pendulus*, and it is most likely that Endlicher described this species from a cultivated specimen, and erred in crediting it to China. A number of horticultural names which have been given to this cultivated plant may be found in Sargent's Sylva, among the synonyms of *Taxodium imbricarium*.

COLLEGE POINT, N. J.

New Plants from Wyoming, XIV

By Aven Nelson

Eriophorum ocreatum

Culms growing singly, from the corm-like crowns of the short slender rhizomes, the base sheathed in old leaf bases, subterete, finely striate, smooth, slender, 2–3 dm. high: sheaths 2–3, 2–3 dm. long, all blade-bearing; blades folded-channelled, obscurely roughened on the margins, broadly linear, rather rigid, short, 5–10 cm. long, tapering to a triangular point, leaves of the involucre 2–4, the longer usually erect and surpassing the inflorescence: spikelets 3–6, subumbellate, the longer-peduncled drooping: scales oval or ovate, obtuse or scarious-lacerate, brown, not obviously veined: bristles numerous, glistening-white, 4–6 times as long as the scales: akene broadly obovate, obtuse, dark brown (nearly black).

This species is most nearly allied to *E. polystachyon* L., but is readily distinguished from it by its more slender habit, shorter and fewer leaves, generally fewer and larger heads, longer and more glistening-white bristles, very different scales and akene. In its few, long-vaginate, short leaves, and in its akene it reminds one of *E. vaginatum* L. In its slender culm which often greatly surpasses the uppermost leaf it suggests *E. gracile* Koch. It is probably a rare plant as thus far I have seen but two collections of it. The type was secured in an open, grassy, subalpine park in the Medicine Bow Mountains, Lincoln Gulch, August 8, 1900, no. 8014.

Hemicarpha aristulata (Coville)

Hemicarpha micrantha aristulata Coville, Bull. Torrey Club, **21**: 36. 1894.

Annual, glabrous, culms few to several, erect, 8–15 cm. high, filiform or capillary, exceeding the capillary leaves: involucral leaves 2–3, unequal, 5–20 mm. long: spikes 2 (sometimes but 1), ovoid, 3–5 mm. long: scales rhombic, acuminate, the body nearly 1 mm. long, scarious-margined, some of the margins turning brown, with a green midrib and inconspicuous nerves; the acumination green, subulate, somewhat spreading, nearly as long as the body of the scale or in the lower ones exceeding: sepal large, as long as the ovule, obtuse or even with a truncate or toothed apex: filament barely exceeding the ovule: style short, its

branches inconspicuously if at all barbellulate: akene obovoid, shorter than the body of the scale.

The above description had been drawn before I was aware of Mr. Coville's variety of *H. micrantha* Vahl, which does not appear in Heller's recent Check-list of North American plants. After carefully considering all that appears in Mr. Coville's excellent and complete discussion of the genus I am still of the opinion that the plant deserves specific rank. Besides the characters pointed out by Mr. Coville which separate it from *H. micrantha*, decided differences in size and form of the floral structures are to be noticed. The following collection greatly extends the range of this species. It was found in a moist, sandy cañon, altitude 2000 m., in company with *Cyperus inflexus*. Halleck cañon, Albany county, July 4, 1900, no. 7428.

Juncus saximontanus

J. xiphioides montanus Engelm. Trans. Acad. Sci. St. Louis, **2**: 481; Bot. Calif. **2**: 290.

As there is a variety *montanus* of *J. Balticus*, this plant, which seems well to deserve specific rank as well as a separate name within the genus, may take the above as indicating its center of distribution.

Trifolium scariosum

Densely caespitose, silvery or cinereous-pubescent throughout, becoming greener and more glabrate with age; the caudex freely branched and clothed with the dead petioles; stemless or nearly so: leaves crowded on the crowns; the leaflets narrowly linear-oblong, widest at the middle and tapering gradually to each end, 1.5–2.5 cm. long, sessile or nearly so; the petioles slender, from twice to several times as long as the leaflets: peduncles surpassing the leaves, like the leaves prostrate-spreading or ascending: the adnate portion of the stipules broad, sheathing, scarious-margined; the free portion linear-acuminate, reduced to merely the greenish midrib, less than 1 cm. long: involucre usually (always?) present, of several very unequal scarious-margined linear-lanceolate segments: heads globose, rather few-flowered: calyx-tube short, narrow-campanulate; its teeth linear, unequal, exceeding or often twice as long as the tube, purple as is also the upper portion of the tube: corolla purple, fading in drying; the standard broadly elliptic, equaling and enclosing the wings which exceed the keel petals: pod 6-ovuled, fewer seeded: the style slender, as long as the pod.

I propose this species as a segregate from *T. dasyphyllum* T. & G. That species was described from James's collections from "Summit of the Rocky Mountains." Specimens from similar situations agree with the original in the brownish pubescence, the absence of an involucre (usually so at least), and the subequal calyx teeth. *S. scariosum* is a larger plant with whiter, more permanent pubescence, a conspicuous scarious involucre, the segments of which are marked by a green midrib. Its petals are uniformly reddish-purple or shading to violet when fresh, while the petals of *T. dasyphyllum* differ in color from each other, the standard being whitish or ochroleucous, barely tinged with purple, the wings and tip of the keel a deep purple hue. The latter, as already stated, occurs in alpine stations while *T. scariosum* occurs at middle elevations, mostly on very stony slopes in the foothills. It is often found on naked ledges where the roots find no soil except in the crevices. Probably not very rare, at least is not in southeastern Wyoming. No. 7270, Laramie Hills, June 20, 1900, is taken as the type.

This seems so strangely characterized that one may venture to name it in the absence of mature fruit. The inflorescence in appearance is much like that of *A. Canadensis*, but of course it cannot even be placed in the same section.

I have met with this plant but once and then it was found in the greatest abundance in the sand dunes of the Red Desert, at the base of Steamboat Mt., Sweetwater county, collected June 9, 1900, no. 7051.

MERTENSIA CILIATA **longipedunculata**

Size of the species, stems more freely branched, stem and branches few-leaved, terminating in long naked peduncles: calyx lobes oblong, subacute, ciliate-margined.

This variety is very common along the streams of eastern Wyoming and apparently occurs at lower altitudes than the species. No. 7321, Chug Creek, Albany county, June 30, 1900, as well as many earlier collections represent it.

Mertensia coriacea

Very leafy from base to summit, tufted, the numerous glabrous stems assurgent, 2–3 dm. long: leaves thick, coriaceous, smooth on both faces except for the flat-topped papillae on the upper sur-

face and on the margins (these are probably the pustulate bases of deciduous hairs); root-leaves numerous, oblong or elliptic, mostly obtuse, 4–8 cm. long, on somewhat shorter petioles; the lower stem-leaves oblanceolate or broadly spatulate, obtuse, tapering into a short petiole, passing into sessile ovate leaves upward; those of the inflorescence crowded, from lanceolate to broadly ovate, acute, 3–5 cm. long: flower-clusters terminal and in the axils of the upper leaves, crowded even in the fruit: calyx-lobes triangular-lanceolate, subciliate, from ⅓ to ½ as long as the tube; of the corolla, somewhat enlarged in fruit: corolla tube 5–6 mm. long, the very villous ring ⅓ its length from the base, the crests in the throat and the 10-toothed ring at the base evident; limb funnelform, only slightly spreading, usually exceeding the tube; the orbicular lobes less than half its length: filaments inserted in line with the crests, membranous, spatulate, as broad or broader than the somewhat longer anthers: seeds 2–3 mm. long, ovate, coarsely rugose.

I have sought in vain for any near ally for this truly alpine species. It was collected about the summits of the Medicine Bow Mts., Albany county, Wyoming, Aug. 1, 1900. It occurred in the rock-slides, mostly in the vicinity of snow banks. The type no. is 7870.

Mertensia coriacea dilatata

Very similar, leaves less coriaceous: inflorescence more open and less leafy: sepals lance-linear, longer (especially in fruit): filaments shorter, dilated, mostly broader than the anthers.

This variety is readily distinguished from the species in the field but less readily in the dried state when the texture of the leaves is not so evident. In herbarium specimens the greater leafiness, especially of the inflorescence, and the broader sepals of the species in contrast with the opener and less leafy inflorescence and the narrower sepals of the variety are the most obvious points of distinction. The habitat of the variety is in general the same as that of the species and it was secured at the same time; no. 7844.

Mertensia coronata

Tufted, from large friable roots: stems glabrous, shining, assurgent, 2–4 dm. long: leaves numerous, large for the plant, smooth below, minutely scabrous above (the hairs very short and curved and sometimes early deciduous from the small pustulate bases); the radical on petioles 2–3 times as long as the oblong,

mostly obtuse blades (5–10 cm. long); the lower stem-leaves similar, tapering into short petioles, the upper ovate-lanceolate, subacute, sessile: flower-clusters terminal and axillary, at length open-paniculate among the large floral leaves: calyx cleft nearly to the base, the lobes triangular-lanceolate, sparingly ciliate, more than half as long as the corolla-tube: corolla tube rather broad, about 5 mm. long, not noticeably hairy within near the base; limb a little shorter than the tube; the lobes suborbicular, abruptly dilated from the rounded sinus: stamens inserted a little below the conspicuous crown of crests in the throat; filaments as long as the anthers, dilated, as broad or broader than the anthers which do not equal the lobes of the corolla.

Probably somewhat related to *M. papillosa* Greene and in some points to *M. foliosa* A. Nelson, but not very closely to either. It seems to be confined to the Leucite formations of south-central Wyoming, occurring among the rocks on the buttes of the Leucite Hills. Collections as follows: Sweetwater county, June 9, 1900, no. 7071 (type); Steamboat Mt., same county and date, no. 7072; N. Vermillion Creek, July 24, 1897, no. 3593.

CASTILLEJA ANGUSTIFOLIA **dubia**

The woody caudex short, giving rise to few or several, slender, simple, ascending or erect stems, 2–3 dm. high: pubescence sparse, cinereous, consisting of fine puberulence and some white, soft hairs: the body or axis of the leaf linear, 3–5 cm. long, 3–5 mm. broad, usually with 1 or 2 pairs of widely divergent linear lobes which are one third to one half as long as the leaf: bracts shorter, the blade and lobes relatively broader and tending to become scarious, decidedly yellowish or at the summit bright yellow: calyx about 2 cm. long, equally cleft to nearly one third its length: corolla scarcely longer than the calyx; the galea and tube subequal; lip almost wanting, not noticeably saccate, truncate and short-toothed.

C. angustifolia Don. is really a species of the far Northwest Its history and characters are well set forth by Mr. M. L. Fernald in Erythea, **6**: 46. In the specimens cited, two from Wyoming are included which possibly are similar to those now before me. While it seems possible that the variety here proposed might properly be constituted a species, yet, as Mr. Fernald's description is drawn, I find no good differences except the yellow color, scantier pubescence (especially in the inflorescence), shorter corolla and sparser leafiness and the longer more open spike in the variety.

Collected by Elias Nelson in the Indian Grove Mts., July 18, 1898, no. 4898a; by L. N. Goodding at Medicine Bow, June 19, 1901, no. 43.

Plantago nitrophila

Allied to *P. Rugelii* but coarser and larger; rootstock short, with a great number of thick fibrous roots: leaves 1 dm. or more in length, mostly oval, sometimes nearly orbicular, obtuse or obtusish, entire or crenately dentate, the 5–7 nerves extending into the pubescent petiole which generally equals or exceeds the thick blade: scape proper about equaling the leaves, whitish with soft crinkly hairs: spike equaling the scape, simple or with 2 or more short spikes from the lowest foliar bracts, moderately thick, crowded: bracts proper ovate, subacute, scarious-margined, keeled and closely appressed, shorter than the mature fruit: sepals nearly orbicular, overlapping each other, scarious with a green midrib, but little more than half as long as the bracts: capsule ovate, 3–4 mm. long, circumscissile near the base: seeds 7–10 in each cell, oblong-elliptic, obscurely wing-angled and delicately reticulated, dark brown.

Readily distinguished from *P. Rugelii* by its coarse leaves, heavy petioles, thick spike, shorter and thicker capsules, the different bracts and sepals, the reticulated seeds as well as the pubescence and larger size of the plant. It is indigenous on wet, grassy saline banks throughout the state but not frequent or plentiful. The type is no. 8417, from an alkali creek bog, near Manville, Converse county, Wyoming, July 17, 1901.

Helianthus Utahensis (D. C. Eaton)

Roots fleshy, fascicled or variously branched from the gnarled central shaft, mostly fusiform, often nearly 1 dm. long: stems generally solitary, simple below, branched above, 1 m. (more or less) high, glabrous, striate: leaves opposite, 7–15 cm. long, all lanceolate, the uppermost narrowly so, only the midrid conspicuous, green, with short sparse incurved hispid hairs which sometimes arise from a slightly pustulate base, sparsely ciliate on the short petiole: heads terminating the many slender, ascending or divaricate branches: peduncles pubescent, slender; those from the lower axils often much elongated: involucre hemispherical; its bracts linear-lanceolate, white-ciliate-pubescent on the margins, 10–15 mm. long, the loose acuminate tips often reflexed: rays usually 14–18, 25–30 mm. long, narrowly oblong: disk yellowish-brown, 1 cm. high and fully as broad; chaff oblong, acute, pubescent on the brownish

tip: akenes oblong, brown, 4 mm. long, nearly as long as the corollas; pappus of 2 linear-lanceolate awns as long as the akenes.

That this is the *H. giganteus Utahensis* Eaton, Bot. King. Expd. 169, I have no longer any doubt. Unfortunately a few specimens have been distributed under another name as a new species. Dr. Rydberg suggested that it might be the above and a comparison since, by the writer, with the type deposited in the National Herbarium confirms that suggestion. Dr. Gray in the Synoptical Flora made it a variety of *H. Californicus* DC., to which indeed it is more closely related. The two are, however, abundantly distinct.

H. Utahensis, very curiously, occurs frequently in herbaria as *H. giganteus* but for what reason is hard to guess. In habit and mode of branching it more nearly resembles *H. Nuttallii* T. & G.

It is common in the middle Rocky Mountains, occurring mostly on sandy stream banks. Some collections of it are: 1578, Laramie Peak, Aug., 1895; 684, Muskrat Creek, July, 1894; Laramie, Oct., 1894; 6757, Yellowstone Park, Aug., 1899; 8135, Granger, Aug., 1900.

CORRECTION

Gnaphalium exilifolium.

G. angustifolium A. Nelson, Bull. Torrey Club, **26**: 357; not *G. angustifolium* Lam. Encyc. **2**: 746.

The Genus Eritrichum in North America

By William F. Wight

Although four different forms under this genus have been recognized in North America, there seems to have been much misapprehension, in regard to some of them at least, as to their relationship to the European *E. nanum* and to each other. A fruiting specimen of one of the Alaskan species not hitherto described has also recently been collected, making a complete description possible, and it is thought that the descriptions given below would therefore be desirable. The author wishes to express acknowledgments to Mr. Frederick V. Coville and Dr. J. N. Rose for criticisms and suggestions in the preparation of the paper, to Mr. F. A. Walpole for the drawings of the nutlets and to Professor Robinson, of the Gray Herbarium, for the loan of material.

The North American species are separable into two main groups, the section *Eueritrichium* of DC.* with four species, *E. arctioides*, *E. argenteum*, *E. Chamissonis* and *E. splendens*, and a second section not before recognized with two representatives, *E. Howardi* and *E. elongatum*. The first section has fruit with a toothed border which is characteristic of *E. nanum*, the type of the genus, figured by Gurke,† while the two last named species have fruit with a marginal ridge-like elevation. These are not referable to the section *Amblynotus* DC.‡ represented by a single species, *E. obovatum* DC., which does not even appear to be congeneric with any of the species under consideration since it differs in having fruit without teeth or any trace of a marginal border, and is convex on the dorsal side instead of flat or with a slight central ridge, as is the case with typical *Eritrichum*.

Eritrichum Schrad.

Eritrichum Schrad. Comment. Goetting. **4**: 186, 1820, based on *Myosotis nana* Vill.

Eritrichium Gaudin, Fl. Helv. **2**: 4. 1828.

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* DC. Prodr. **10**: 125. 1846.

† Gurke, in Engler and Prantl, Die natürlichen Pflanzenfamilien, 4^{3a}: 108. *f. 43. E.* 1894.

‡ DC. *l. c.* 128.

Synopsis of the Species

Dorsal surface of the nutlet margined with a ridge-like elevation, but without a toothed border.

Leaves with a fine and rather loose or spreading pubescence; dorsal surface of the nutlets smooth or rather hispidulous; flowers 4–6 mm. in diameter. 1. *E. elongatum.*

Leaves with a dense and closely appressed pubescence; dorsal surface of the nutlet papillose and hispid with short bristly hairs; flowers 7–9 mm. in diameter. 2. *E. Howardi.*

Dorsal surface of the nutlet with a border of subulate or triangular teeth.

Leaves with closely appressed, strigose pubescence; flowers in dried specimens 9–13 mm. in diameter. 3. *E. splendens.*

Leaves with rather loose, villous or hirsute pubescence; flowers in dried specimens 4–7 mm. in diameter.

Dorsal surface of the nutlet ovate; teeth of the border about half the length of the body of the nutlet; flowers 4–6 mm. broad.. 4. *E. argenteum.*

Dorsal surface of the nutlet nearly circular in outline, the teeth of the border as long as the body of the nutlet; flowers 5–7 mm. broad.

Flower cluster usually raised on a distinct, sparingly leafy stalk, commonly 2–5 or sometimes even 12 cm. high. 5. *E. aretioides.*

Flower cluster sessile among the terminal leaves of the stem. 6. *E. Chamissonis.*

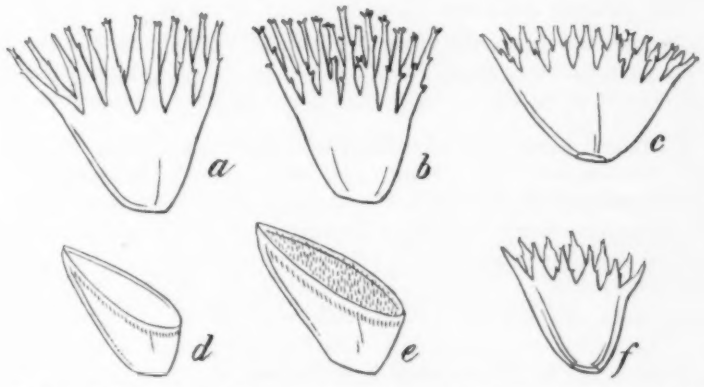
1. **Eritrichum elongatum** (Rydb.)

Eritrichum aretioides elongatum Rydb. Mem. N. Y. Bot. Gard. 1: 327. 1900.

A low and tufted or matted plant in external appearance very closely resembling *E. argenteum*, but the pubescence commonly rather more loose and spreading and seldom with a silvery appearance; the closely overlapping leaves 5–8 mm. long, 1.5–2 mm. broad, oblanceolate, acute or obtuse, those on the flowering branches linear or oblong-linear; flowering branches 1–6 cm. long; flower cluster raceme-like or more or less compact: calyx lobes linear: corolla 4–6 mm. in diameter, its limb bright blue: nutlet usually shining, about 2 mm. long on the inner angle, the dorsal surface usually smooth, very rarely with a few minute bristles, margined by a rather sharp, ridge-like elevation, but without a toothed border.

Two plants are cited by Dr. Rydberg, one collected June 26, 1897, in the Spanish Basin, Montana, by Rydberg and Bessey (no. 4891) and the other collected in 1883 in the Belt Mountains, Montana, by Scribner (no. 173); the type, however, is not indicated and the first named plant is therefore here designated as such, a duplicate of which, in fruit, is in the United States National Herbarium.

This plant, briefly described by Dr. Rydberg as a variety of *E. aretioides*, differs from both the true *aretioides* and the Rocky Mountain plant hitherto identified as such in the nutlets not having a toothed border, but instead a ridge-like margin which allies it to *E. Howardi*. A description of the nutlets was omitted in the original description, although well-developed nutlets were found



Nutlets of *Eritrichum*, × 10. *a*, *E. aretioides*; *b*, *E. chamissonis*; *c*, *E. splendens*; *d*, *E. elongatum*; *e*, *E. Howardi*; *f*, *E. argenteum*.

on the plant in the United States National Herbarium collected by Rydberg and Bessey (no. 4891). It differs from *E. Howardi*, its nearest relative, in being a smaller plant, and in its oblanceolate leaves, its spreading pubescence and its smaller flowers. A plant of alpine or subalpine distribution in northern Colorado, Wyoming and western Montana to eastern Oregon.

Specimens have been examined as follows:

COLORADO: Alpine Ridges, Middle Park, 1861, *C. C. Parry*; Gray's Peak, 11,000–14,000 ft. alt., 1885, *H. N. Patterson, 109*.

WYOMING: Head of Big Goose Creek, Big Horn Mountains, 1893, *Frank Tweedy, 43*; Dome Lake, 1896, *Aven Nelson, 2433*.

MONTANA: Belt Mountains, 9,000 ft. alt., 1883, *F. L. Scribner, 173*; 6–7,000 ft. alt., 1887, *R. S. Williams, 1078*. Park county, 1889, *Frank Tweedy*. Spanish Basin, Gallatin county, 5–6,000 ft. alt., 1897, *Rydberg & Bessey, 4891*. Old Hollowtop, near Pony, about 9,000 ft. alt., 1897, *Rydberg & Bessey, 4890*. Bald Mountain, 10,000 ft. alt., 1880, *Sereno Watson, 245*.

IDAHO: Pleasant Valley, June 25–30, 1871, *G. N. Allen;* June 25–30, 1871, *Thos. C. Porter.*

OREGON: Summits of the Wallowa Mountains, 1886, *Wm. C. Cusick, 1430.* Subalpine ridges of the Wallowa Mountains, near the lake, 1899, *Wm. C. Cusick, 2268.*

2. ERITRICHUM HOWARDI (Gray) Rydb.

Cynoglossum Howardi Gray, Syn. Fl. **2**[1]: 188. 1878.

Omphalodes Howardi Gray, Syn. Fl. **2**[1]: 423. 1886.

Eritrichum Howardii Rydb. Mem. N. Y. Bot. Gard. **1**: 327. 1900.

A matted plant, densely strigose-hairy with closely appressed hairs; leaves 7–13 mm. long, 1–2 mm. broad, linear-spatulate, acute, flowering branches 1–6 cm. high: flower cluster more or less compact when on a short flowering branch, but raceme-like when on an elongated one: calyx lobes linear-lanceolate, acute: flowers 7–9 mm. in diameter, the limb of the corolla bright blue: nutlets with the dorsal surface either papillose or with minute bristly hairs and margined with a rather sharp ridge-like elevation, the sides of the nutlet smooth and shining.

E. Howardi is distributed in the mountains of western Montana, and has been collected in the Cascade Mountains in Washington. It was originally described from material collected by Winslow J. Howard in the "Rocky Mountains in Montana."

Specimens have been examined as follows:

MONTANA: Without special locality, "about 1866," *Winslow J. Howard.* Mt. Helena, 1883, *Wm. M. Canby, 242.* Helena, May 1, 1886, *R. S. Williams;* June, 1888, *F. D. Kelsey.* Yogo, Belt Mountains, July 25, 1888, *R. S. Williams.* Park county, 1889, *Frank Tweedy.*

WASHINGTON: Cascade Mountains, 1882, *Frank Tweedy, 130.*

3. **Eritrichum splendens** Kearney, sp. nov.

A strigose-hairy herb, the caudex much branched and forming a mat of numerous short, sterile, leafy shoots, and of fewer elongated flowering ones which attain a height of from 4–13 cm.; lower leaves narrowly oblanceolate, 1.5–2 cm. long, 2–3 mm. broad, tapering to a slender petiole, the upper leaves on the flowering stems sometimes linear or oblong-linear, sessile, the upper surface less hairy than the lower: racemes few-flowered, the lower peduncles elongated at least in fruit: calyx lobes oblong, obtuse or

broadly acute: corolla large, the limb bright blue, its lobes broadly obovate, the tube about equalling the calyx; dorsal surface of the nutlet slightly hispid or tuberculate, the teeth of the border two thirds as long as the body of the nutlet and with bristly points on their margins and apex, the bristles at the apex sometimes showing a tendency to become glochidiate.

Type specimen in the United States National Herbarium, collected July 9, 1901, on Old Man Creek, a tributary of the Koyukuk River, Alaska, by W. C. Mendenhall.

E. splendens differs from all other species herein noted in its larger flowers, and from other Alaskan species in its larger leaves and closely appressed, strigose pubescence, and in the shorter teeth of the nutlet.

Mr. Kearney's description was from plants in flower only, collected by G. M. Stoney in the Jade or Baird Mountains. A specimen with both fruits and flowers has since come to hand and is now taken as the type for the above description.

The specimens examined are as follows:

ALASKA: Old Man Creek, July 9, 1901, *W. C. Mendenhall*, Jade or Baird Mountains, August 2, 1885, *G. M. Stoney*.

4. **Eritrichum argenteum** sp. nov.

A low and rather densely villous plant of several short, sterile branches forming a tuft or mat 2 or 3 cm. high, this often exceeded from 1–5.5 cm. by the flowering branches; the pubescence commonly silky and shining or silvery in appearance: leaves on the sterile branches closely overlapping, oblanceolate or oblong, obtuse or acute, 5–10 mm. long, 1.5–3 mm. broad, those on the flowering branches sometimes linear or linear-oblong and usually less villous than the lower ones: flower cluster compact when sessile among the leaves at the end of a branch or raceme-like when borne on an elongated branch: calyx lobes linear, densely villous: flowers in dried specimens 4–6 mm. in diameter, the limb of the corolla bright blue: nutlets with a dorsal border of triangular teeth, these distinctly visible in the young nutlets soon after pollination and even discernible under a low power of the compound microscope as soon as the flower is fully open; teeth when mature about half the length of the body of the nutlet distinctly connate at the base and bearing minute bristles on their margins and apex.

Type specimen in the United States National Herbarium, collected July 31, 1895, among rocks above timber line, at an eleva-

tion of 12,000 feet, on a mountain northwest of Como, Colorado, by Crandall and Cowen (no. 36).

E. argenteum hitherto identified as *E. aretioides*, differs from both the Alaskan plants with villous pubescence, which are its nearest relatives, in the following characters; from *E. Chamissonis* in its smaller leaves and its usually somewhat elongated flowering branches, and from both *Chamissonis* and *aretioides* in its more silvery pubescence, its more villous calyx, its smaller flowers and the shorter teeth of the nutlets; it differs from other Rocky Mountain species in having nutlets with a toothed border, and has a more southern range, occurring on the high mountains of central Colorado and northeastern Utah.

The specimens examined are as follows:

COLORADO: Rocky Mountains, Lat. 39°–41°, 1862, *Hall & Harbour, 440.* Near Boulder City, "alpine," 1873, *H. N. Patterson, 26.* Mountain northwest of Como, 12,000 ft. alt., 1895, *Crandall & Cowen, 361.* Gray's Peak, 12,000 ft. alt., June 19, 1873; *J. M. Coulter*, 1872; 12–13,000 ft. alt., *A. Gray*, July 18, 1892, *C. S. Crandall.* Saddle House, Pikes Peak, 12,500 ft. alt., 1896, *F. H. Knowlton, 16.* Central Colorado, 13,000 ft. alt., 1873, *John Wolf.* Without special locality or date, *E. Palmer.*

UTAH: Uinta Mountains, 12,000 ft. alt., 1869, *Sereno Watson, 849.*

5. ERITRICHUM ARETIOIDES (Cham.) DC.

Myosotis aretioides Cham. Linnaea, **4**: 443. 1829.

Eritrichum aretioides DC. Prodr. **10**: 125. 1846.

Eritrichum nanum aretioides Herder, Act. Hort. Petrop. **1**: 535. 1871–1872.

Omphalodes nana aretioides Gray, Proc. Am. Acad. **20**: 263. 1885.

A tufted or matted plant of numerous sterile branches with overlapping leaves and fewer elongated sparingly leafy ones bearing a compact flower cluster at the end, the sterile branches 3–5 cm. high, the flowering ones exceeding these from 2–5 or even 12 cm., the whole plant villous with a rather loose or spreading pubescence; leaves of the sterile branches 5–12 mm. long, 1–2.5 mm. broad, oblanceolate or the upper ones sometimes nearly linear, acute, or the lower ones rarely obtuse, those on the flowering branches linear or oblong-linear, obtuse or acute: calyx lobes

oblong, acute or broadly acute: flowers in dried specimens 5–7 mm. in diameter, the limb sky-blue: nutlets about 1.5 mm. long on the inner angle, the teeth of the dorsal border about as long as the body of the nutlet, more or less connate at the base and bearing minute bristles on their margins and apex.

A beautiful plant growing on sandy or gravelly soil near the shore from St. Lawrence Island and Port Clarence to Cape Lisburne in Alaska, and on Herald Island, St. Lawrence Bay, Kayne Island and Kamchatka, in Siberia. The original description was based on specimens from St. Lawrence Island and St. Lawrence Bay.

Specimens have been examined as follows:

ALASKA: Port Clarence, 1899, *Coville & Kearney, 1970;* 1901, *F. A. Walpole, 460, 532, 984.* Cape Riley, July 5, 1894, *James F. White.* Reindeer Station, July 3, 1894, *James F. White.* Cape Thompson, 1881, *John Muir.*

SIBERIA: Herald Island, 1881, *C. L. Hooper.* Whalen, July 18, 1894, *James F. White.* Kayne Island, 1853–56, *C. Wright.*

6. ERITRICHUM CHAMISSONIS DC.

Eritrichum Chamissonis DC. Prodr. **10**: 125. 1846.

Eritrichum nanum Chamissonis Herder, Act. Hort. Petrop. **1**: 535. 1871–72.

Omphalodes nana Chamissonis Gray, Proc. Am. Acad. **20**: 263. 1885.

Very closely resembling the preceding but rather more densely villous, and the flower cluster sessile among the leaves at the ends of the branches, the latter however sometimes elongated 1 or 2 cm. in fruit; the closely overlapping leaves about 10 mm. long, 2–3.5 mm. broad, oblanceolate, but the lower portions covered by the successively overlapping leaves and the exposed portion obovate to ovate, obtuse or broadly acute: flower cluster compact: calyx lobes oblong, obtuse; flowers in dried specimens 5–7 mm. in diameter, the limb of the corolla sky-blue: nutlets about 1.5 mm. long on the inner angle, the teeth of the dorsal border as long as the body of the nutlet, more or less connate at the base and bearing rather strongly marked bristles on their margins and apex, those at the apex showing a tendency to become divergent or sometimes even slightly recurved.

A common plant on St. Paul Island, Alaska, and also col-

lected on the main land at Port Möller, Alaska Peninsula. It was originally described from specimens collected at St. Lawrence Bay, Siberia, and Kamchatka.

Specimens have been examined as follows:

ALASKA: St. Paul Island, August 3, 1891, *J. M. Macoun;* 1895, *True & Prentiss, 40, 68;* 1890, *Wm. Palmer, 139;* August 7, 1891, *C. Hart Merriam;* without date, *Kusmischscheff;* without date, *H. W. Elliott;* Port Möller, July, 1890, *C. H. Townsend.*

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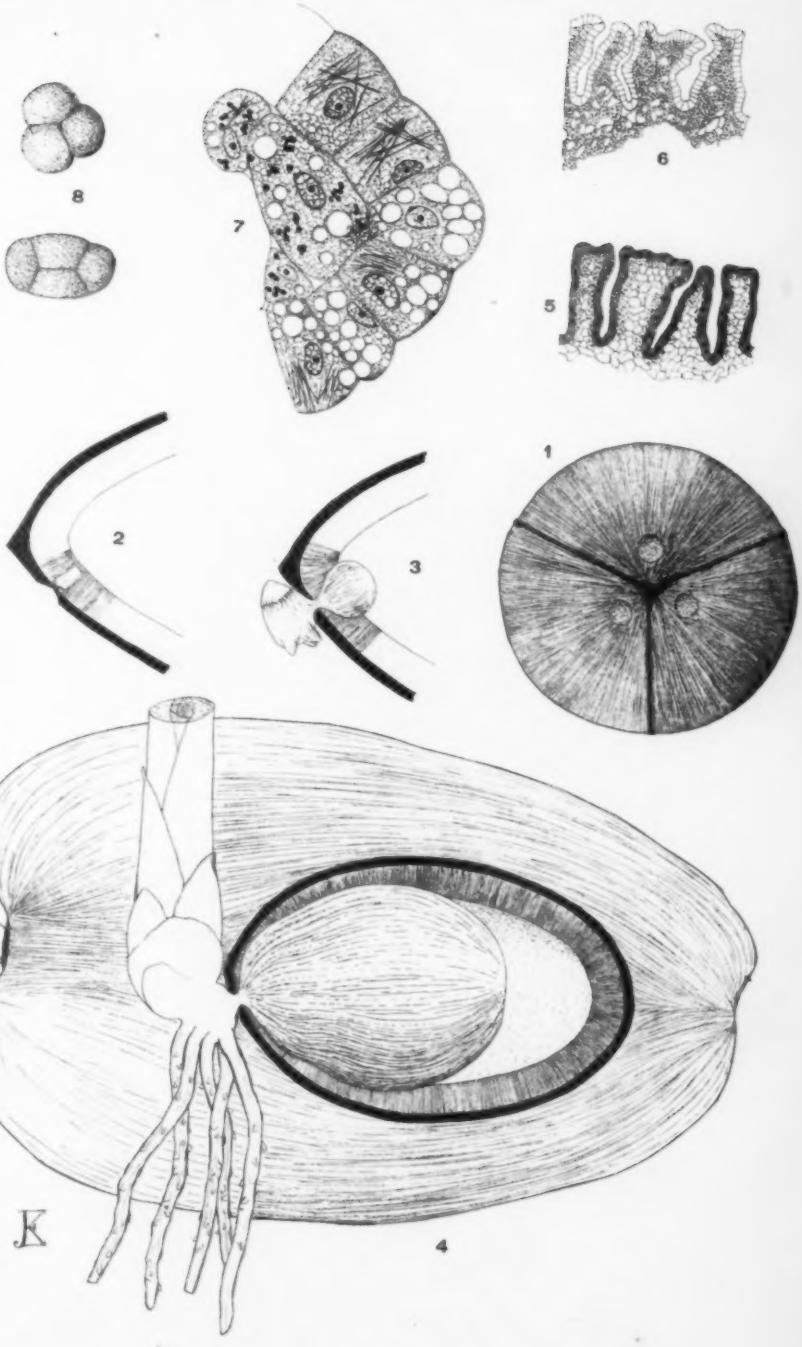

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